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Integrated Science Instrument Module (ISIM)

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NGST Integrated Science Instrument Module

- What is it?
- Who will build it?
- Programmatics and Schedule
- Community Instrument Studies
- GSFC Pre-Phase A Feasibility Study

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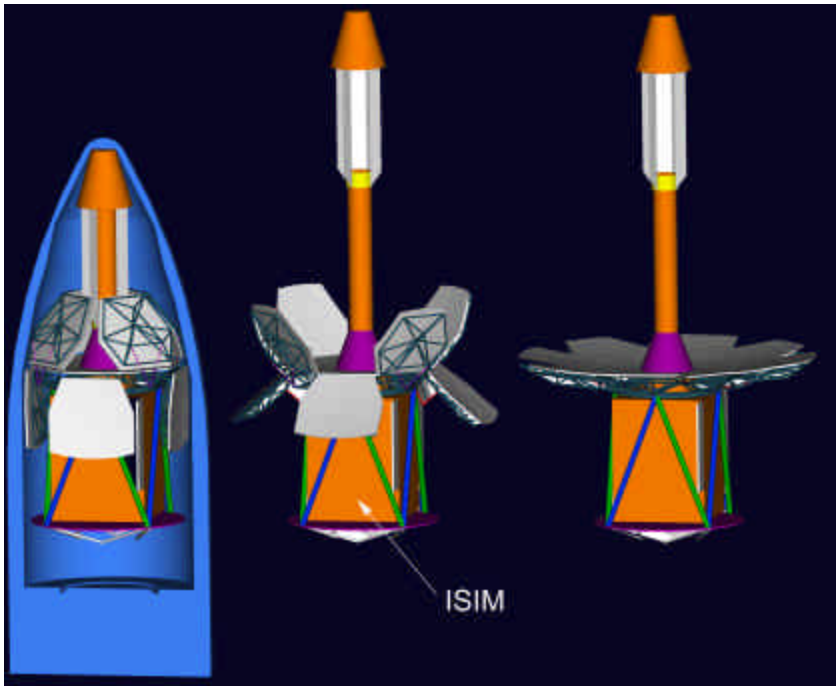
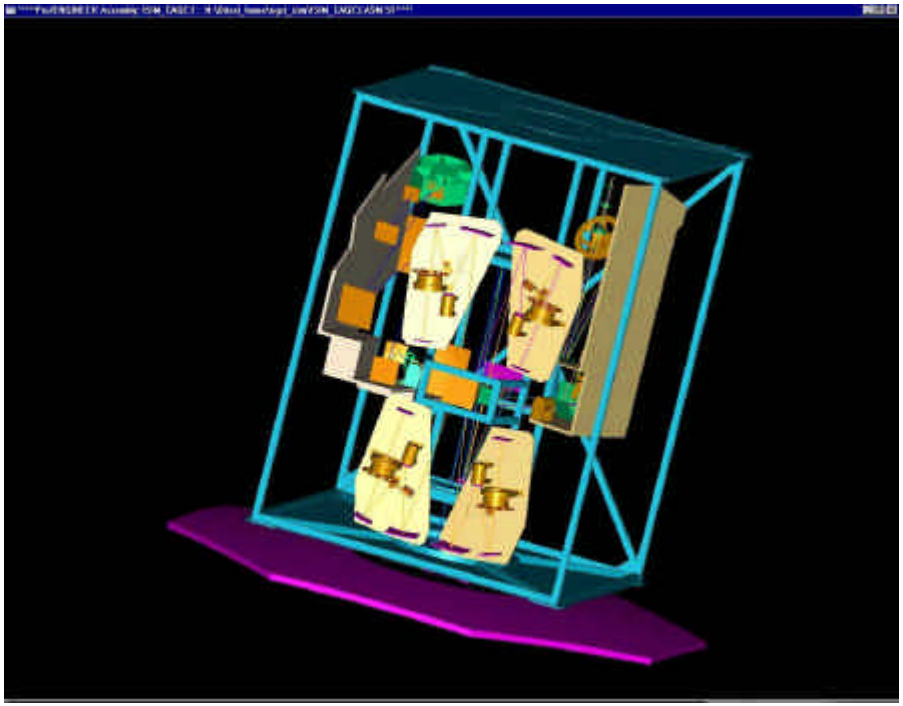
NGST Integrated Science Instrument Module

- One of three major subsystems that comprise NGST
- The ISIM system consists of a cold instrument module and a data system located in the SSM
- The cold instrument module contains:
  - OTA optics
  - NASA, ESA, and CSA science instruments
  - Support systems (thermal, electronic, etc)



NGST 8m: EELV Medium 5m Faring



Yardstick Integrated Science Instrument Module

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ISIM Development

- GSFC will lead an IPT for development of the ISIM
  - members include: STScI, ESA, CSA, Prime Contractor
- ISIM system designed, constructed and integrated at GSFC
  - structure, thermal, electronics, flight data system, flight software, and GSE
  - flight qualified module delivered by GSFC to Prime as GFE
- Science instruments for ISIM procured from US, ESA, and CSA science communities and delivered to GSFC for integration into ISIM

ISIM Development Approach

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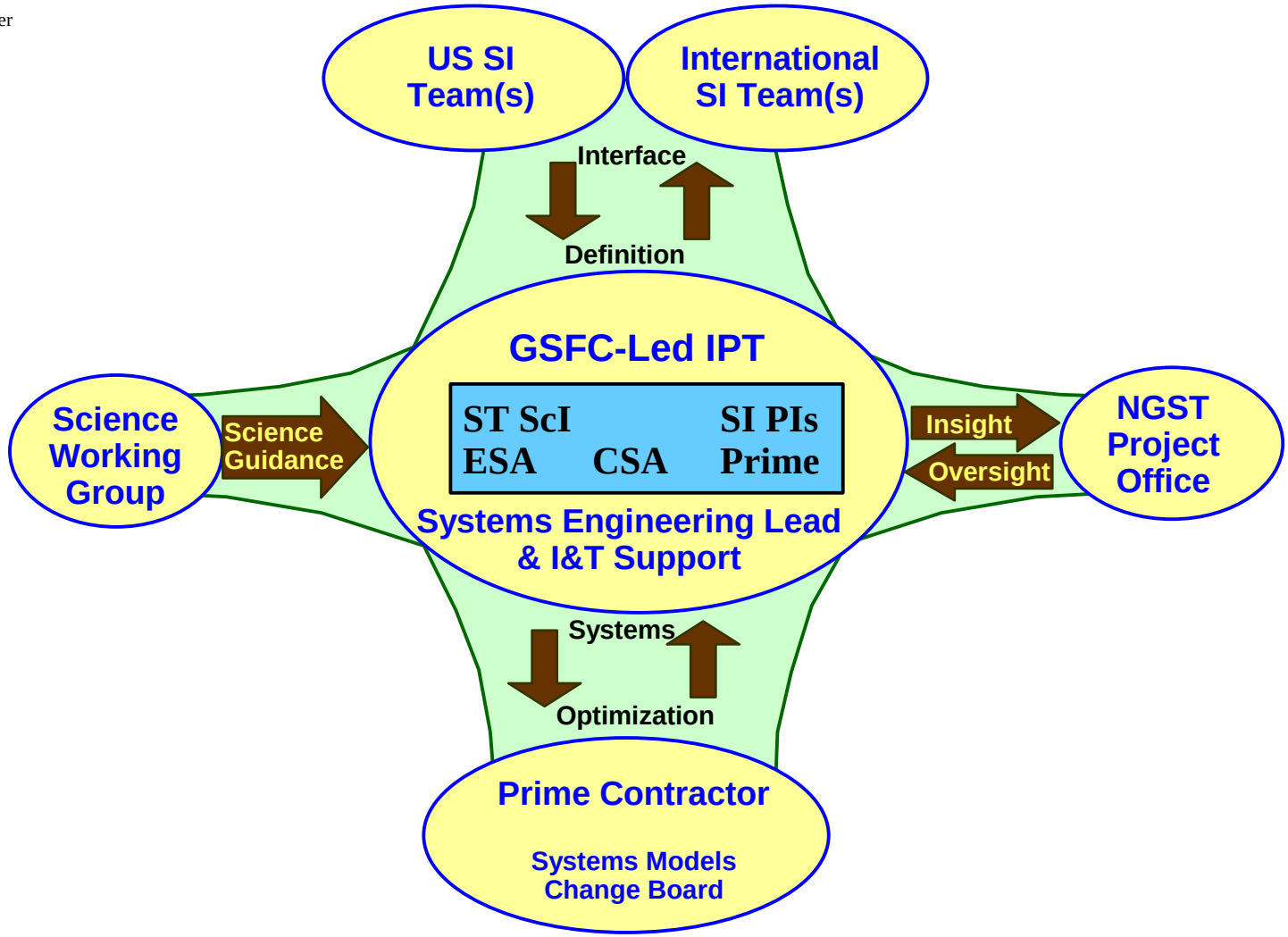

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ISIM Roles and Responsibilities

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GSFC IPT

- ISIM Structure
- Thermal Subsystem
- Common Detector & Mech Electronics
- Field Relay Optics
- Data Analysis Flight Processor & Software
- Mission Control Flight Processor & Software
- System I&T
- Module Common GSE

SI Teams: US, ESA, CSA

- Science Team
- Science Program
- SI Module Structure
- SI Mechanisms
- SI Specific Electronics
- SI Optics
- SI Module I&T
- Module Specific GSE

- Science instrument teams procured through AO process
- ISIM integrator is GSFC led IPT
  - IPT Members join as acquisition process proceeds: STScI, SI PIs, ESA/CSA, Prime Contractor
- SI modules delivered to GSFC for integration into ISIM
- ISIM delivered by GSFC as GFE to prime contractor

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Science Instrument (SI) Procurement Rationale

- GOALS
- Science instrument selection via NASA AO process at mid-formulation phase (2/02)
- close SI concept trade early in phase A to:
  - enable smart customer instrument allocation among NASA, ESA, and CSA
  - enable architecture level system trades to proceed
  - focus ISIM technology development spending to retire risk early
- PROCESS
- process reviewed by: ASWG, SRB, NESR, HQ, Origins Subcommittee
- prioritization of generic instrument concepts/capabilities
  - science capability: Ad Hoc Science Working Group (ASWG)
  - technical feasibility and cost: NGST Project team review
  - recommendation issued by Project Scientist
    - draft open for public comment (1/00)
- RESULT
- generic SI concepts evaluated prior to inter-agency allocation AO solicitation
- wide field of offerors -- participation in pre-phase A not required

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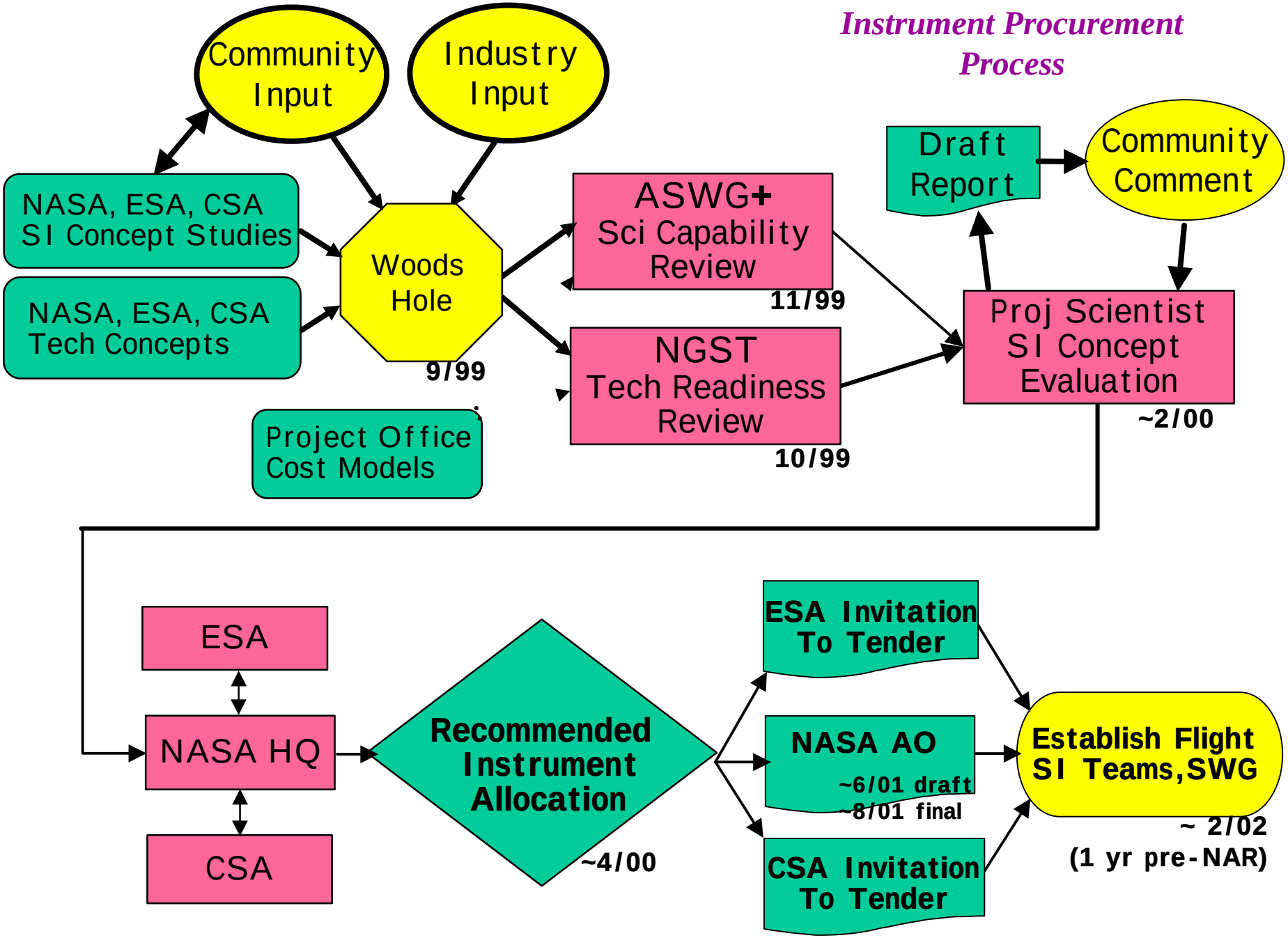
Instrument Procurement Process



ejs 2/16, after M.Greenhouse, 2/11

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Pre-AO Concept Evaluation Process

Ad Hoc Science Working Group

- Select generic concepts/capabilities for instruments that enable the NGST Phase A science requirements and DRM.
  - wide field imaging and spectroscopy over 0.6 - 10+ microns
  - diffraction limited angular resolution at 2 microns
  - Zodiacal background limited sensitivity over 0.6 - 10+ microns

Technology Readiness

- Committee of engineers and scientists convened by NGST Project Scientist
- Assess generic concepts for technical feasibility and readiness relative to NGST development schedule

Project Scientist

- Consolidate ASWG and Technology Readiness Review findings into report
  - draft available for public comment

Inter-Agency Negotiation

- Recommended NASA/ESA/CSA instrument allocation

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Instrument Acquisition Timeline

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Instrument Procurment Timeline: Version 3.0										
ISIM Milestones				**Year**	**Month**	**NGST**	**NGST Milestones**			
NRA 1: Concept Studies	NRA 1			1998	6	Pre-A				
					7					
					8					
					9					
					10		SRB 2			
					11					
					12		NESER			
AAS Town Meeting #1				1999	1					
					2					
					3					
					4	A				
					5					
AAS Town Meeting #2					6					
		Studies Due 1 Aug			7					
NRA 2: Instrument Technologies	NRA 2	Concept			8					
	Year 1	Evaluation and			9					
Technical Concept Evaluation		Allocation			10					
Science Concept Evaluation					11					
					12					
AAS Town Meeting #3				2000	1					
Project Scientist Report					2					
					3					
NASA/ESA/CSA Allocation Complete					4					
		Specs	Interface		5					
					6					
ESA Instrument Letter of Commitment					7					
	Year 2				8					
					9					
					10	B				
					11					
					12					
				2001	1					
					2					
					3					
					4					
					5					
AO Draft Release: Instruments & SWG		DRAFT AO			6					
Pre-Proposal Workshop					7		Single Prime Select			
AO Release	Year 3	AO Solicitation			8					
	(final)				9					
Proposals Due		AO Peer Review			10					
					11					
					12					
Instrument & SWG Selection Complete				2002	1	on going				
	on going				2					
					3					
					4					
					5					
					6					

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NRA 2: Instrument Technologies & Modeling

- Instrument technologies for multi-object and integral field spectroscopy
- Conventional and MEMS cryogenic infrared tunable filters
- Laboratory and ground-based demonstrations of NGST science instrument concepts
- Laboratory demonstration of long life flight cooling systems for 6 K IR focal plane arrays
- Techniques for characterization and operation of detectors
- Modeling and simulations relevant to enhanced understanding of NGST instrument requirements

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Instrument Procurement: Critical Path Milestones

- **1. Concept Studies: 6/98 - 8/99 (currently in progress)**
  - US and European community concept studies: ongoing through 8/99.
  - GSFC baseline ISIM system design study: ongoing
  - ESA ISIM system design study: ongoing through 8/99.
- **2. Concept Review: 9/99 – 4/00**
  - ASWG reports on scientific capability relative to DRM
  - NASA reports on technical and cost feasibility relative to NGST schedule
  - Project Scientist issues consolidated report
  - ESA and CSA SI roles identified
    - ESA and CSA instrument contributions may be excluded from NASA solicitation
  - HQ approves SI concept suite for US AO solicitation
- **3. Flight Instrument Procurement: 6/01 – 2/02**
  - Flight instrument call for proposals draft release: 6/01
  - Pre-Proposal workshop: 7/01
  - Flight instrument call for proposals: 8/01
  - Flight instrument proposals due: 10/01
  - NASA and ESA flight instrument selection complete: 2/02

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Instrument Procurement: Other Schedule Items

- Enabling Technologies and Modeling Studies: 9/99 – 9/02
  - NRA for community studies focusing on enabling technologies and performance modeling.
- Flight Science Working Group (SWG) solicitation coupled with NASA, ESA, and CSA instrument solicitations
  - Selects SWG scientists not affiliated with instrument teams
  - Flight SWG selection 2/02
    - science leadership team in place ~ 1 year before Non Advocate Review

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US Instrument Development Timeline

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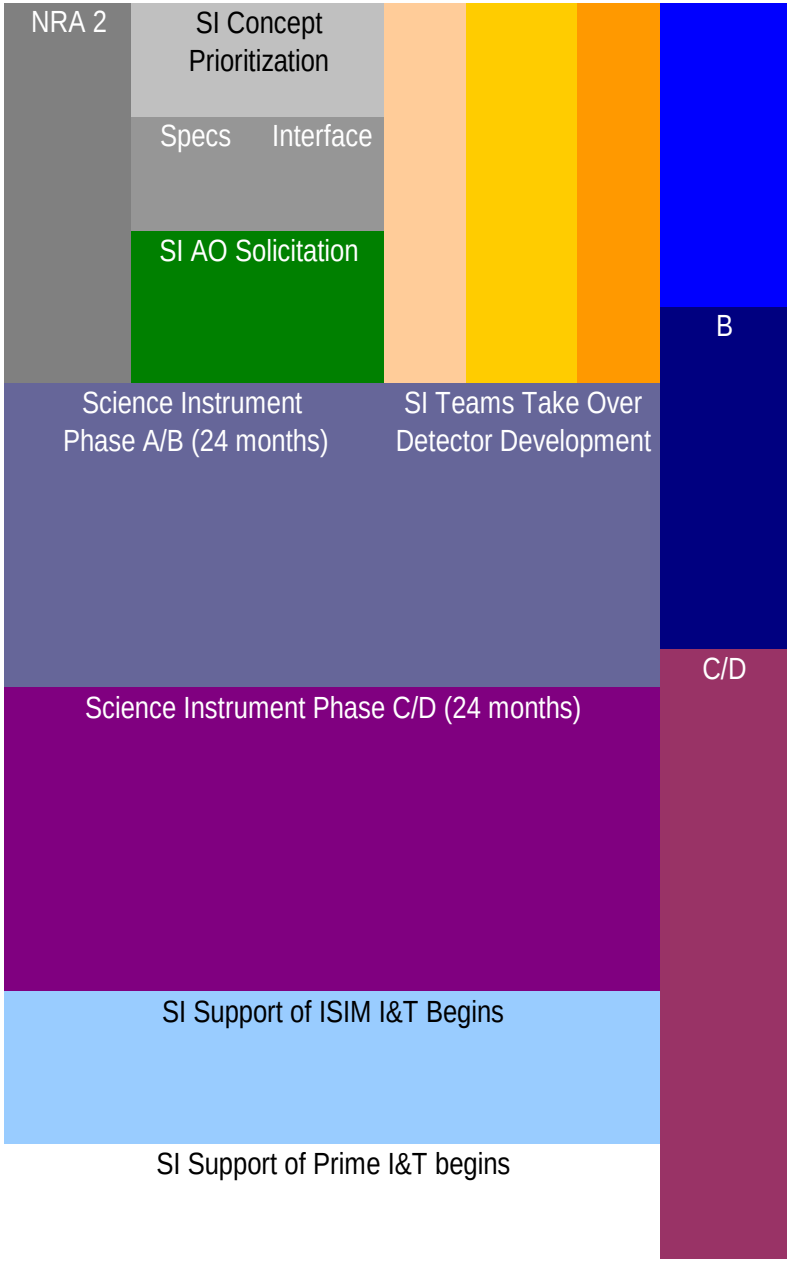
Code S Detector Funding 3 Yr Cycle	2000	4 1 2 3
2nd Community Workshop on Detectors	2001	4 1 2 3 4
Instrument & SWG Selection Complete	2002	1 2 3 4
SI PDR, NGST NAR	2003	1 2 3 4
Observatory Phase C Start SI CDR Observatory CDR	2004	1 2 3 4
Flight Detector FPAs Delivered To SIs	2005	1 2 3 4
SIs Delivered TO GSFC (L - 25 months)	2006	1 2 3 4
ISIM Delivered To Prime (L - 15 months)	2007	1 2 3 4



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US Community Instrument Concept Studies

Solicited from external community via NRA with NASA HQ peer review

Six teams, selected during Jun 98, 1 year performance period

- J. Bechtold, T. Greene: U. of Arizona & Lockheed Martin Corp.
  - 0.3 - 40 micron imaging, spectroscopy, and ISIM layout
- J. Graham: U. of California & ITT Industries & Lawrence Livermore Labs
  - 1 - 15 micron Fourier transform imaging spectroscopy
- J. MacKenty: STScI/ Ball Aerospace/ GSFC
  - 1 - 5 micron multi-object spectroscopy with MEMS micro-mirrors
- H. Moseley: GSFC
  - MEMS micro-shutter aperture control for multi-object spectroscopy
- G. Serabyn: JPL
  - 5 - 28 micron camera/spectrometer and Sorption cryo-cooler
- J. Trauger: JPL
  - 5 - 30 micron high contrast coronagraph with deformable mirror

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CSA NGST Science Instrument Studies

Three science instrument studies are underway in Canada

1. Near-IR MOS/IFS:

   David Crampton (HIA/DAO) + CAL (Ottawa)

2. Visible Imager:

   Paul Hickson (UBC) + CAL (Ottawa)

3. IFIRS Imaging FTS:

   Simon Morris (HIA/DAO) + Bomem(Quebec)
   (collaboration with US Graham/ITT study)

ESA Instrument Concept Studies

- Consortium selected by ESA to perform a trade study of integral field and multi-object spectrograph options
- A detailed design study will be performed on one option.
  - O. Le Fevre (PI), LAS, Marseille, France
  - R. Bacon, Observatoire de Lyon, France
  - R. Davies, Durham University, UK
  - R.S. Ellis, Cambridge University, UK
  - G. Monnet, European Southern Observatory, Garching, Germany
  - N. Thatte, MPE, Garching, Germany
  - T. de Zeeuw, Leiden Observatory, the Netherlands
- Details on: http://www.astrsp-mrs.fr/www/ngst2.html
- Optical camera study team selected 12/98

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GSFC Baseline ISIM Design Study

- Study goals:
- Demonstrate mission science feasibility,
- Assess ISIM engineering and cost feasibility,
- Identify ISIM technology challenge areas,
- Enable smart customer procurement of NGST.

- Architecture constraints:
- Integration with the "Yardstick" and other NGST 8 m architectures that are intended for packaging in an EELV or Ariane 5 meter class fairing.

- Ongoing progress can be monitored via the NGST & ISIM web sites:
  - http://ngst.gsfc.nasa.gov/
  - http://www701.gsfc.nasa.gov/isim/isim.htm

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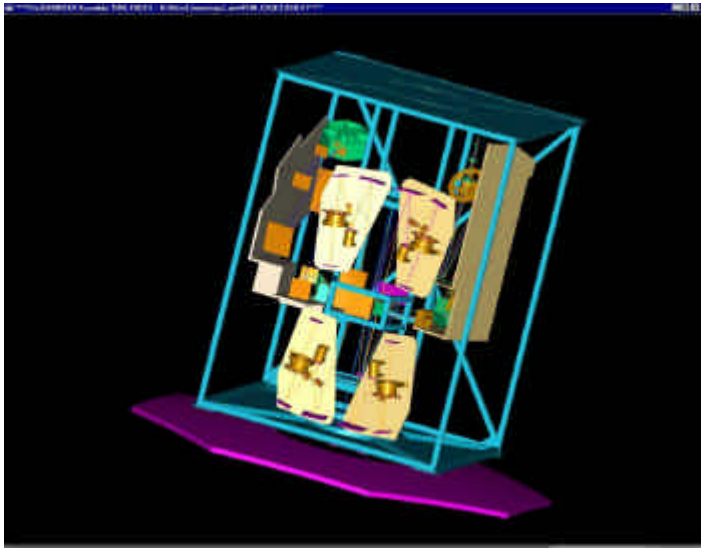
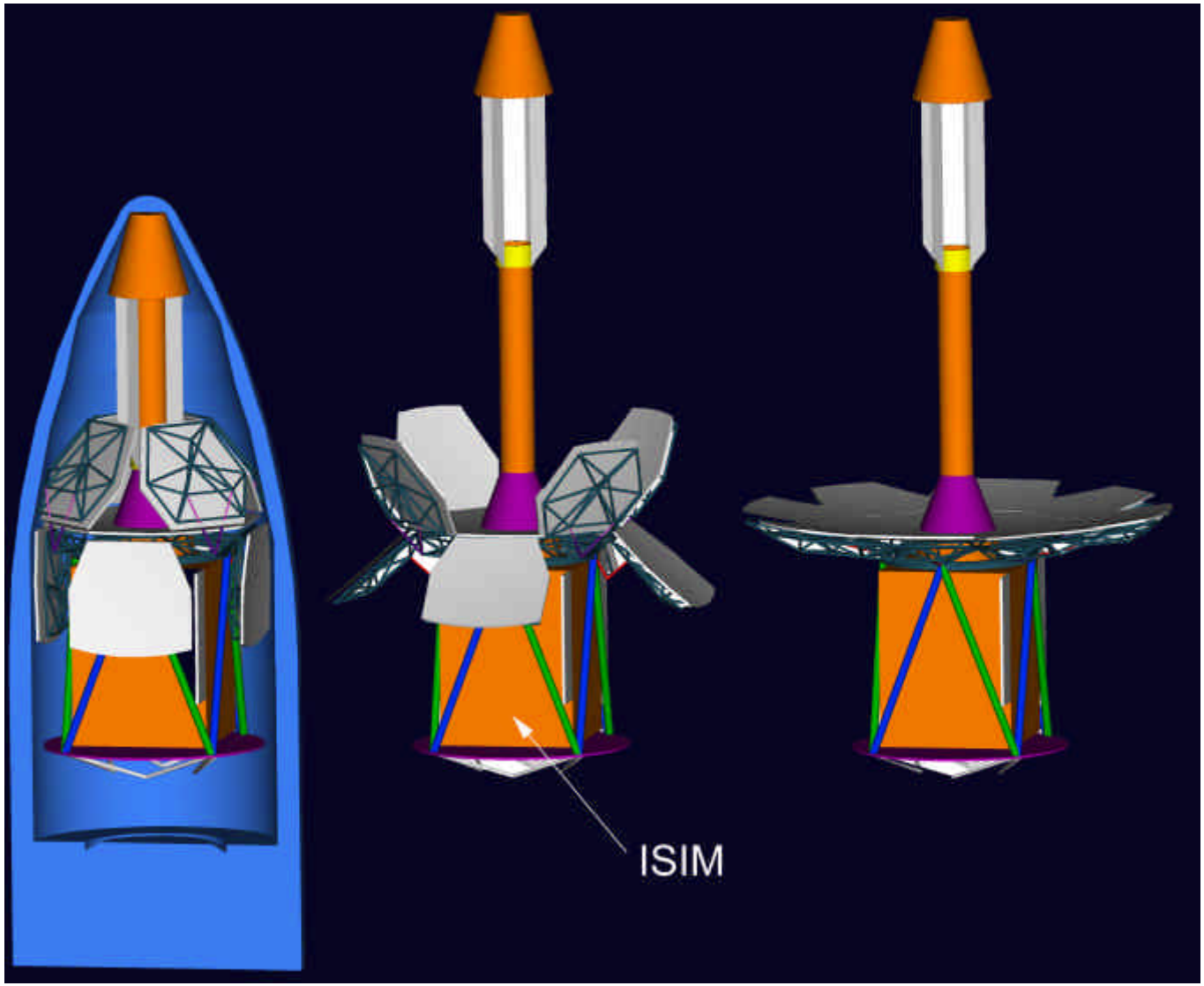
Baseline ISIM design evolution

- 1996
  - single integrated instrument
  - top level concept only
- 1998
  - modular instrument
  - detailed engineering model
    - opto-mechanical layout
    - thermal constraints
    - OTA constraints
    - package volume constraints



NGST 8m: EELV Medium 5m Fairing



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ISIM Baseline Science Instruments

Instrument	Wavelength (μm)	Bandwidth	FPA	Pixel Pitch	Plate Scale (10^{-3} arc-sec)	Aperture Control (arc-min)
Near-IR Camera (1 of 4[1])	0.6 – 5.3	R = 2,5 fixed filters R = 50,200 tunable filters	4096 x 4096	27	29	quad-beam divider: four 2 x 2 fields
Near-IR Spectrometer	0.6 – 5.3	R = 300, 3000 gratings	4096 x 4096	27	100	reflective slit mask: 2048 x 2048 micro-mirror array, 100 μm pixels
Mid-IR Camera/Spec	5 – 28	broad-band filters grisms, cross-disperser	1024 x 1024	27	230	slit selection + 2 x 2 camera

1. A quad-beam divider (pyramid mirror) apportions a 4 x 4 arc-min field of view over 4 identical cameras.
2. Holes in pyramid mirror facets used to form simple coronagraph.

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OTA and ISIM System Optical Schematic

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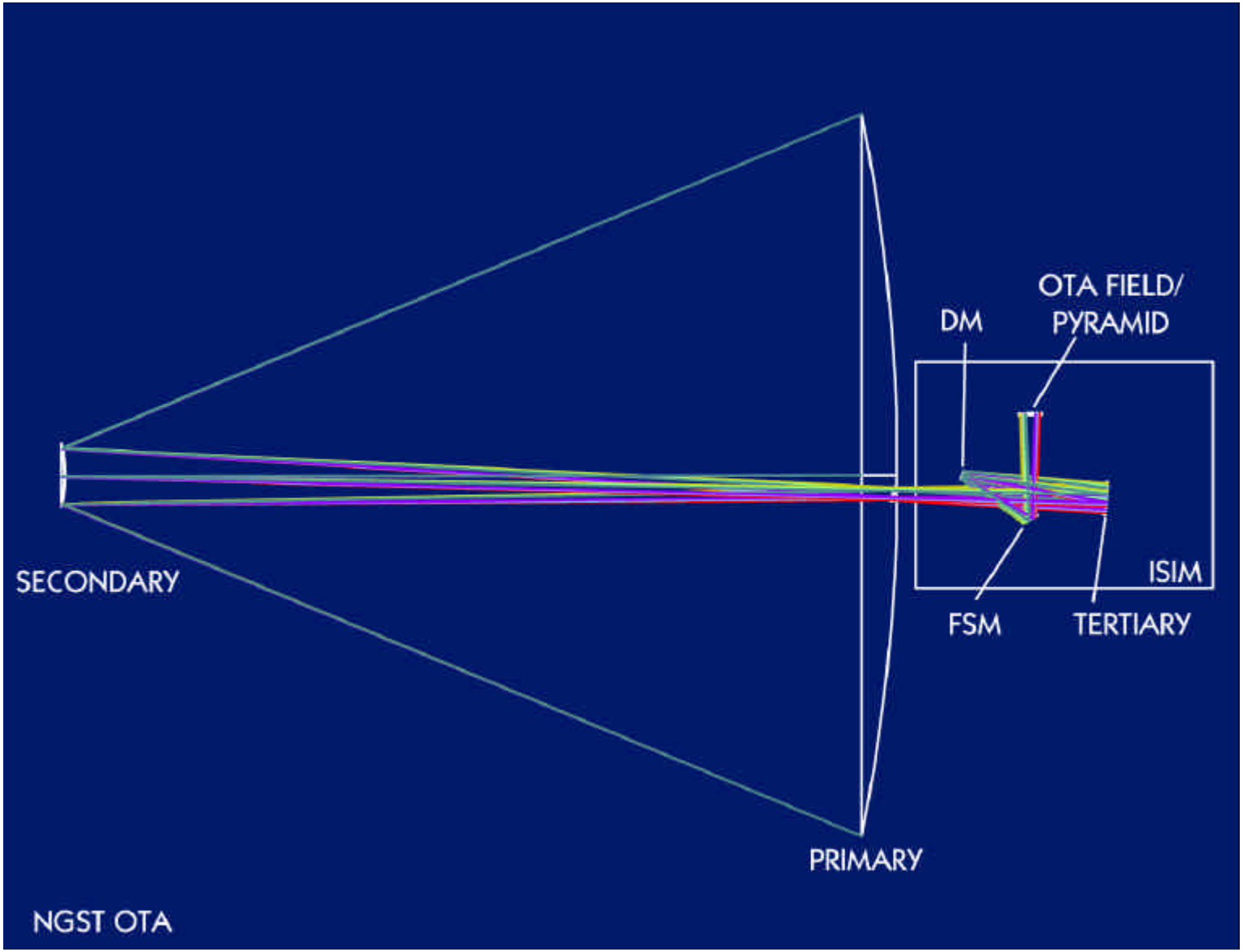

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NGST ISIM Focal Plane Layout

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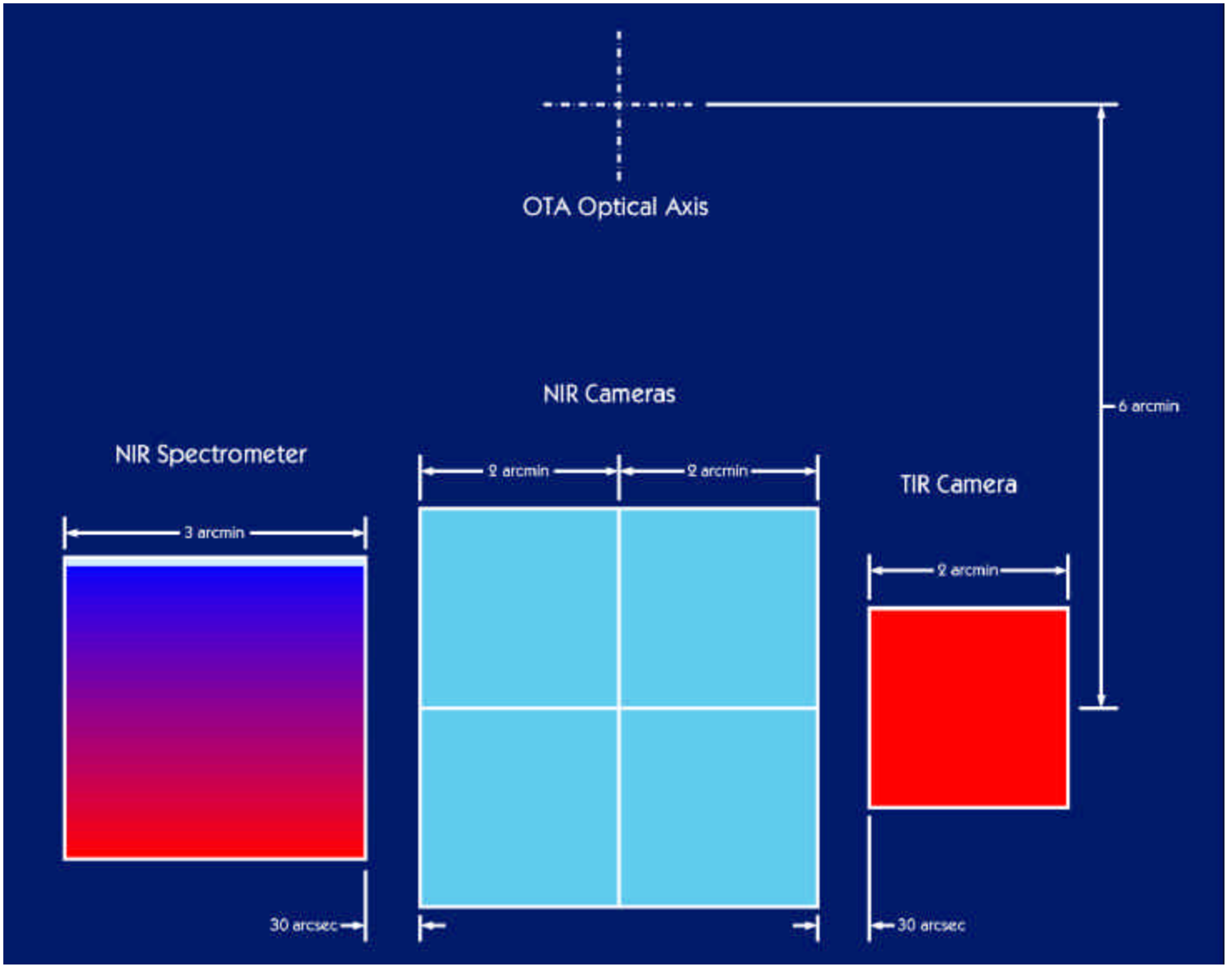

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RMS Wavefront Error Vs Field Position

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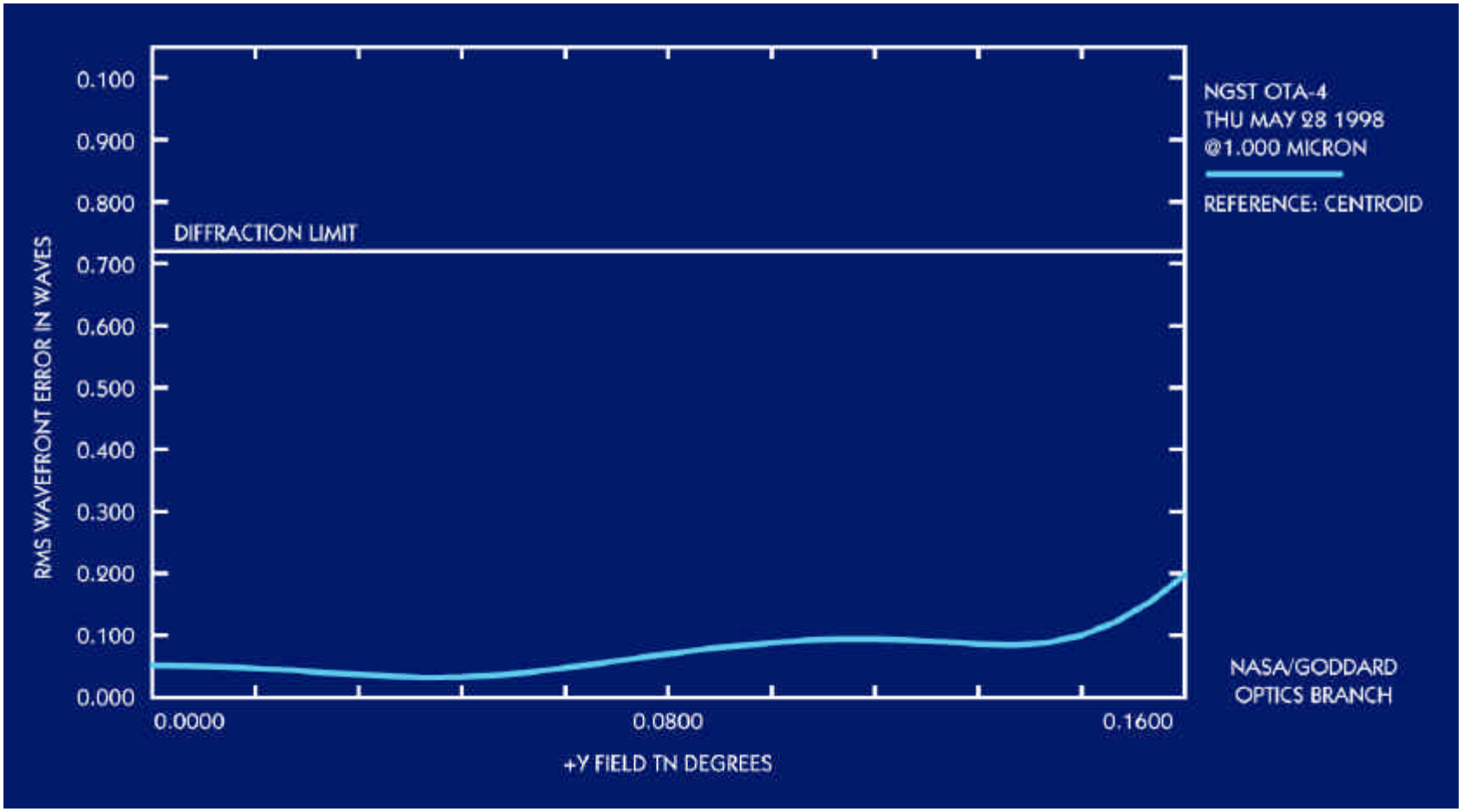

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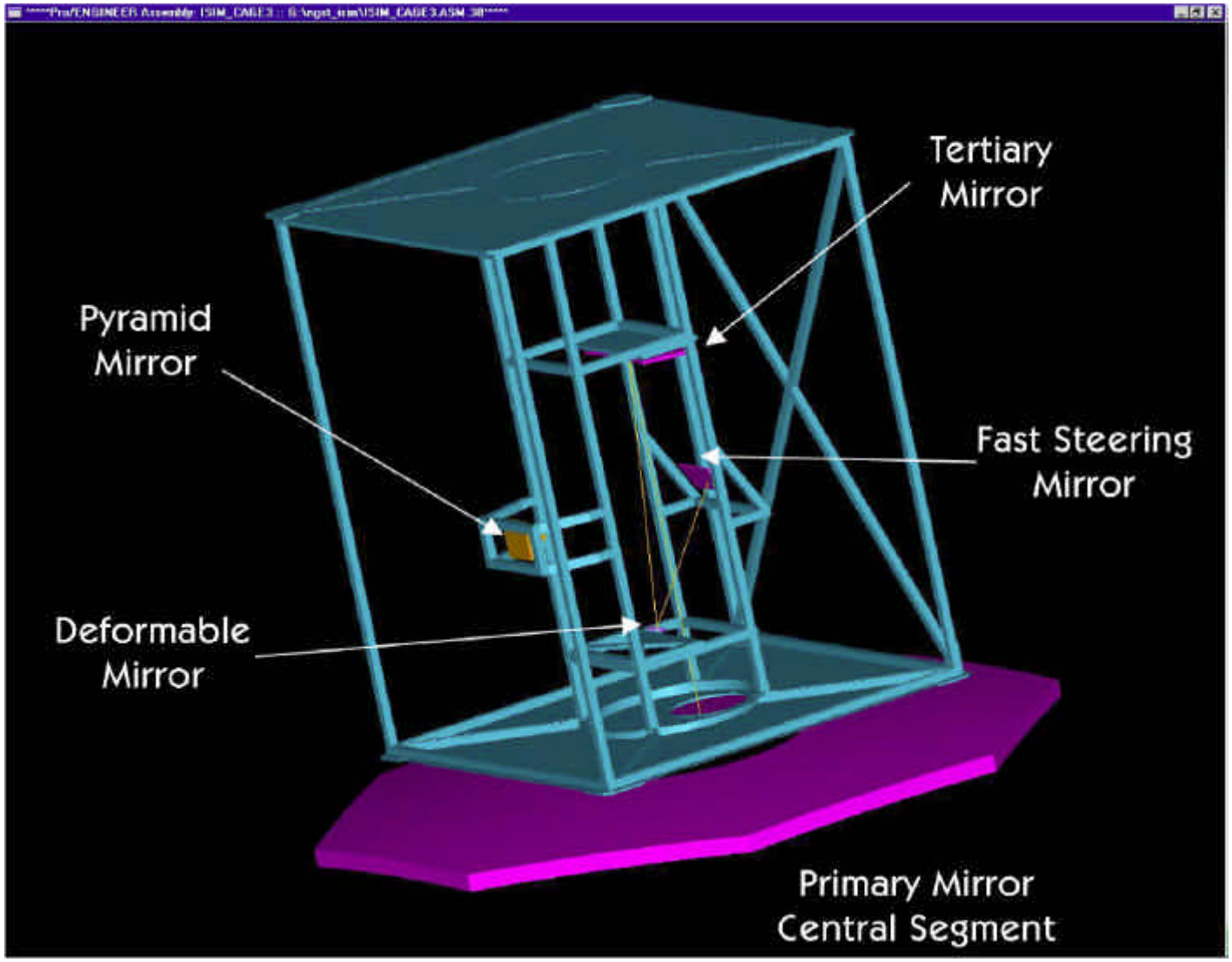
The ISIM instruments are located in an off-axis position.

This configuration yields excellent image quality over a 24 arc-min diameter field.



The OTA tertiary mirror, deformable and fast steering mirror assemblies, and pyramid mirror integrate into the ISIM in a modular fashion.

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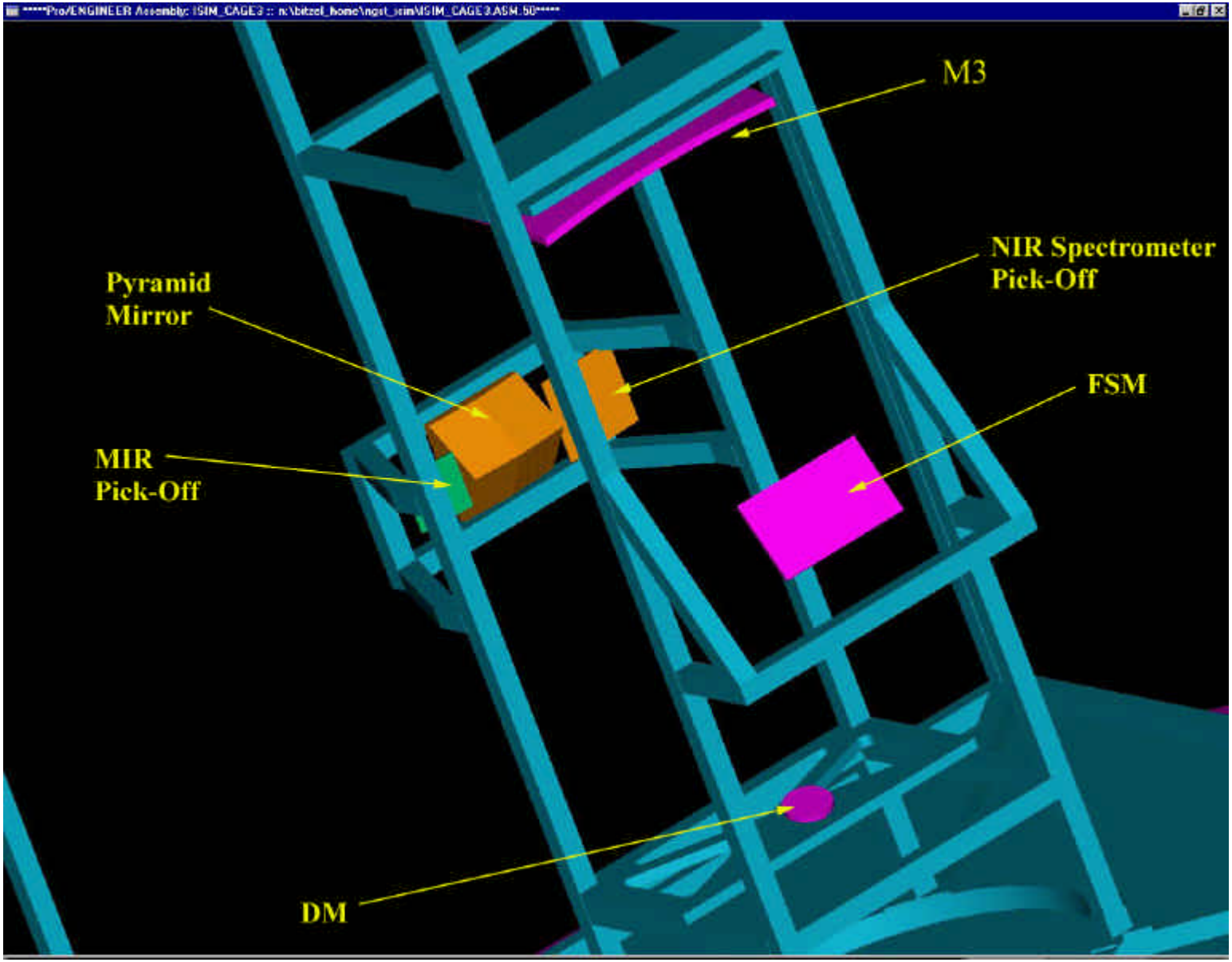

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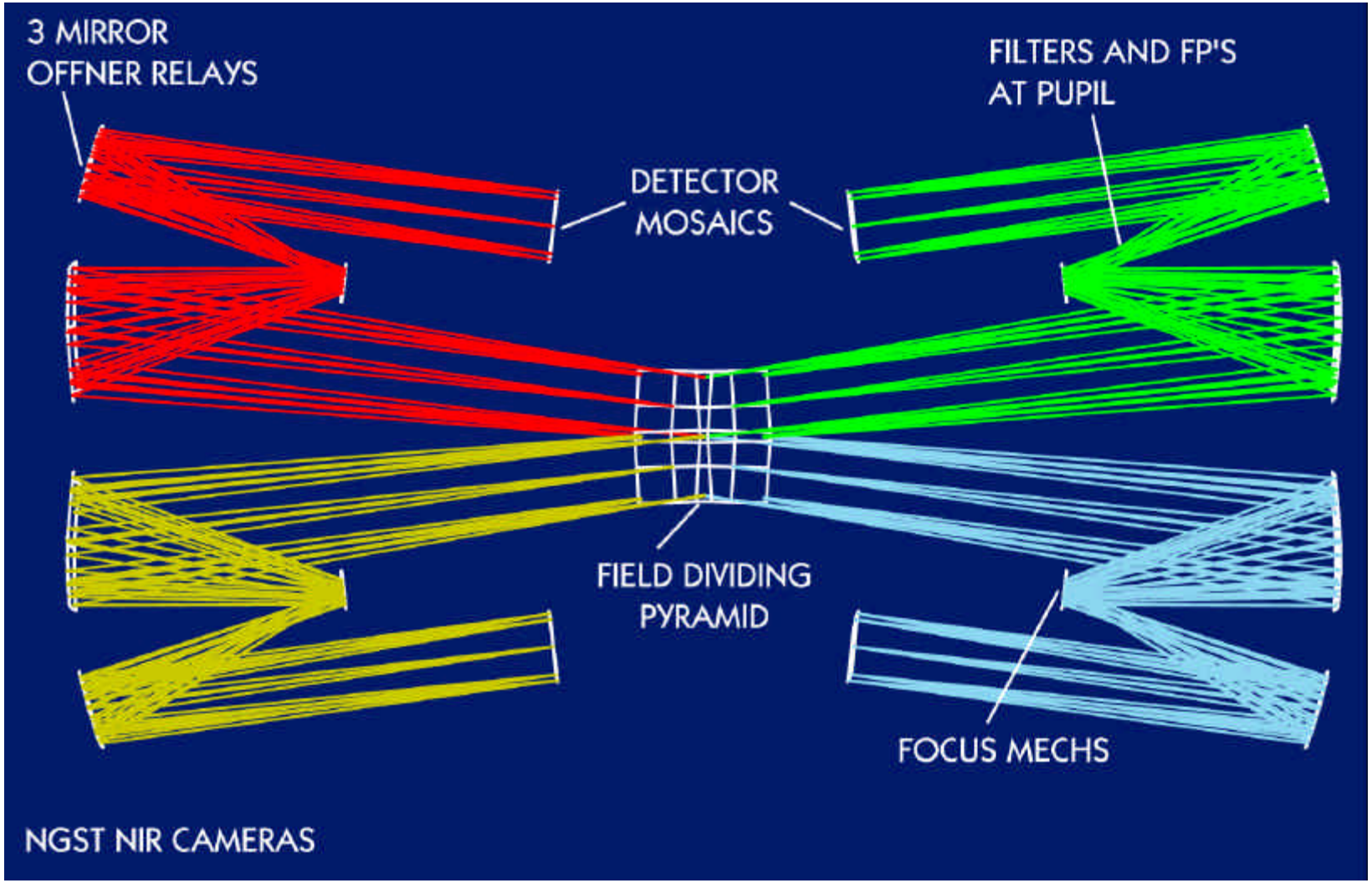
Near-IR Wide Field Camera Optical Schematic



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Near-IR Wide Field Camera Optical Schematic

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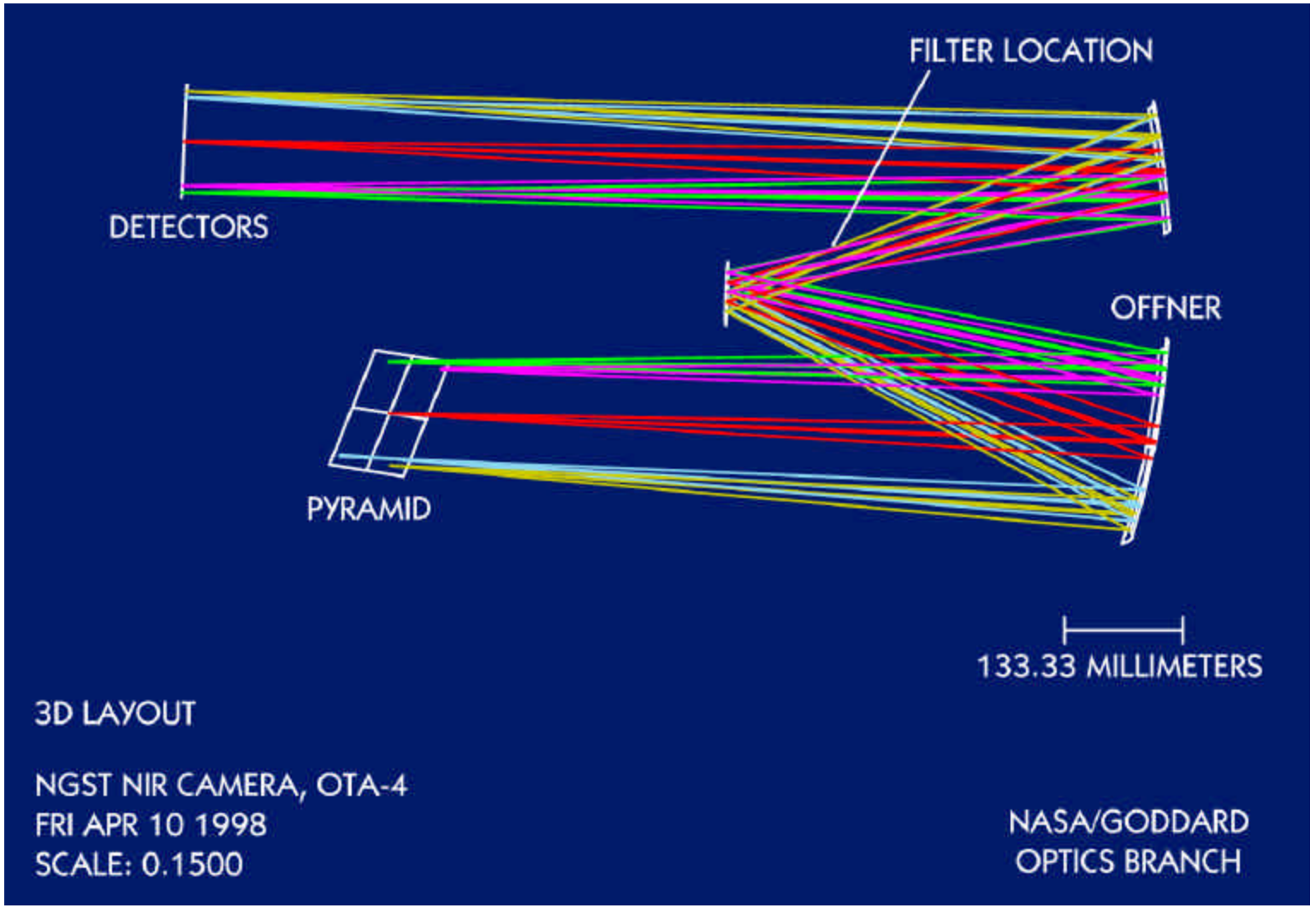

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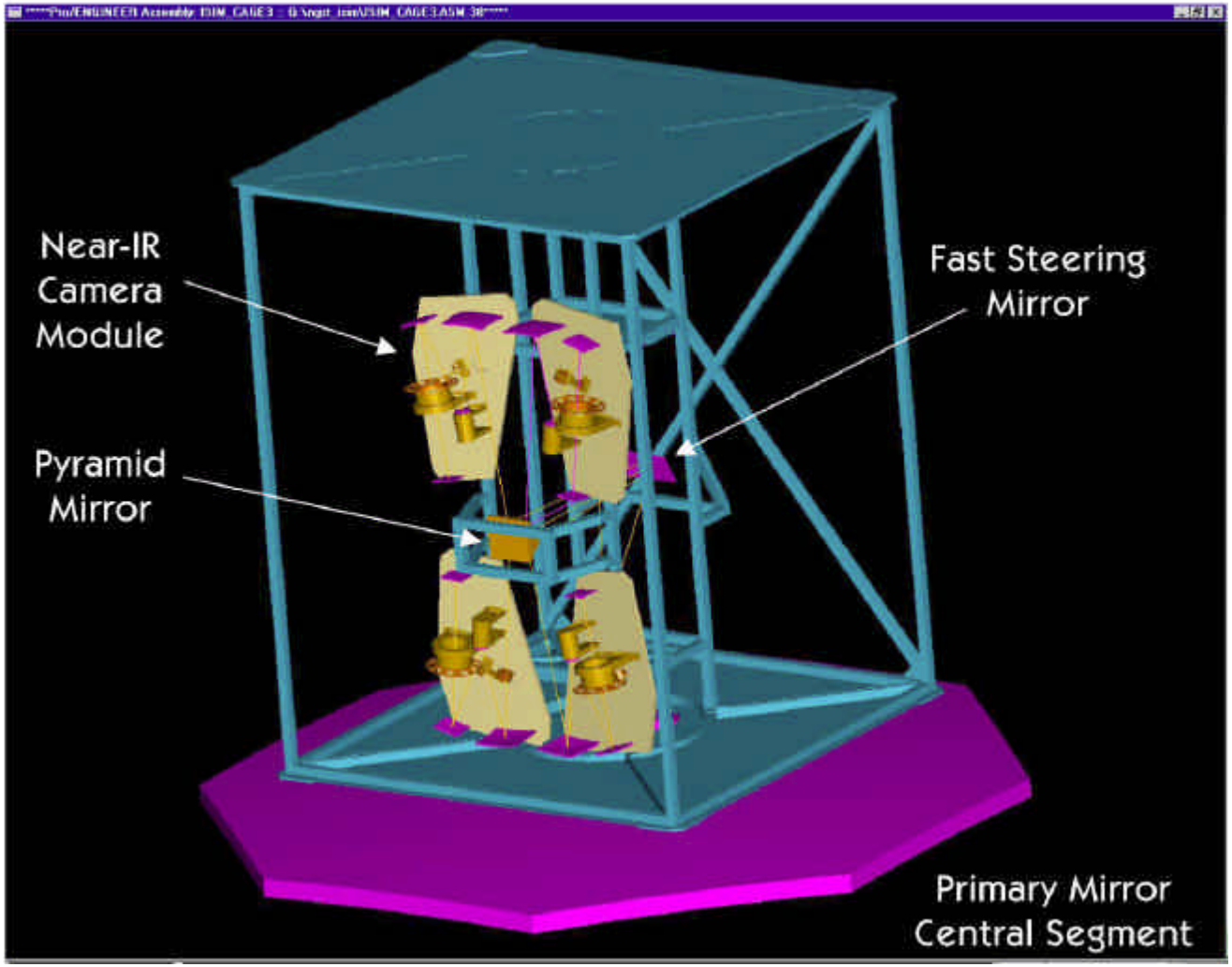
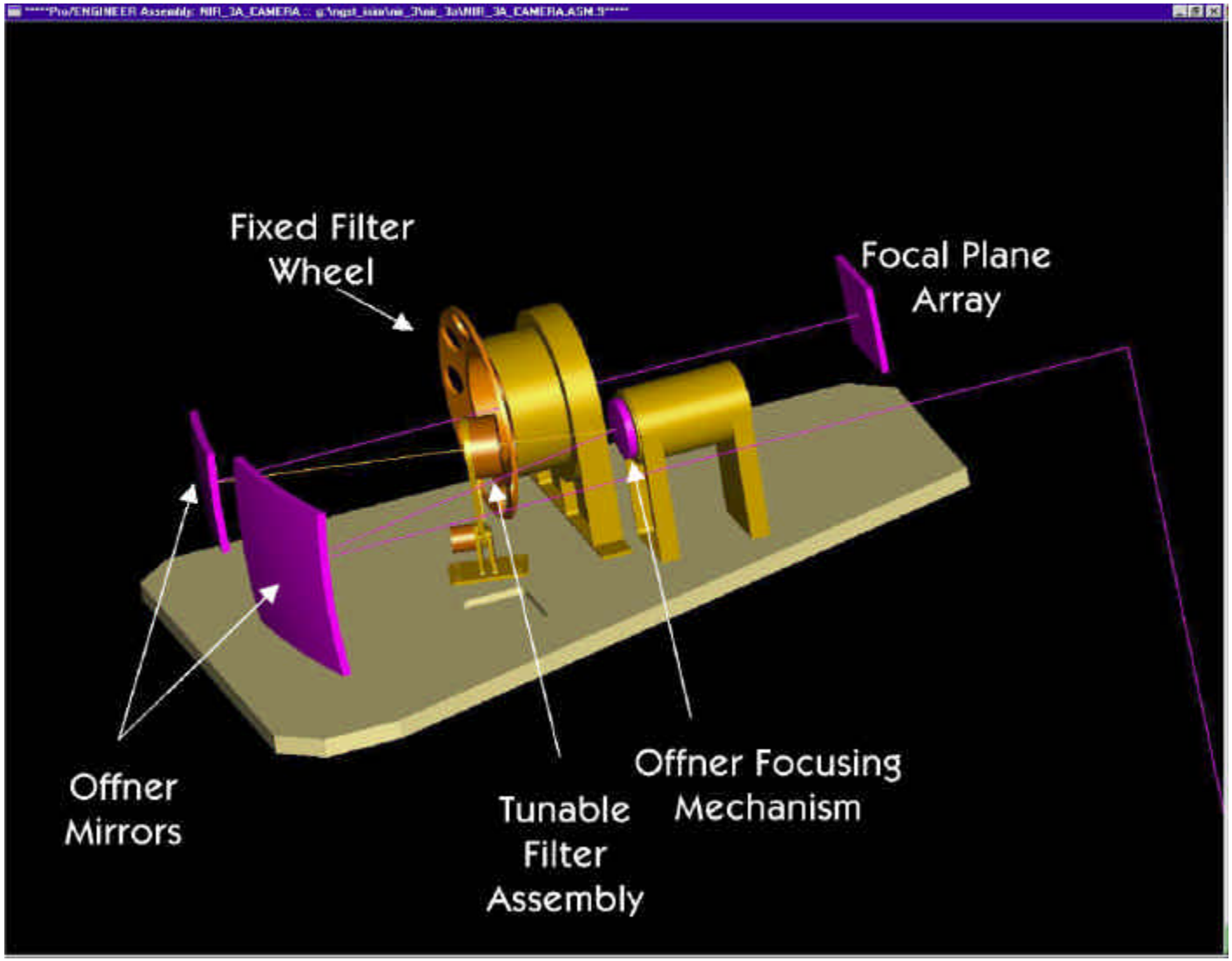
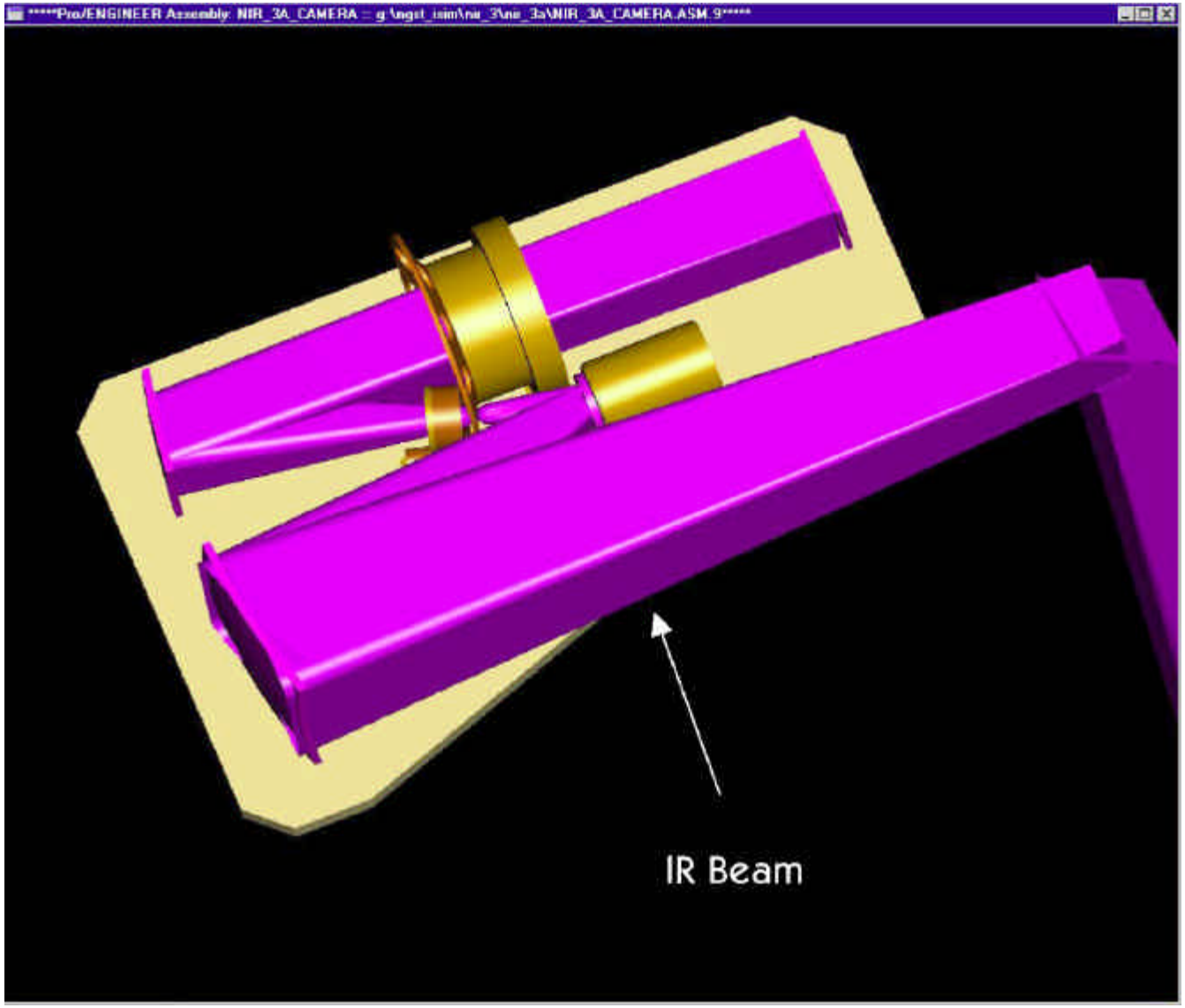


The ISIM near-infrared wide field camera employs a pyramid beam divider to apportion a 16 square arc-min field of view over four identical camera modules. Each module utilizes a 4096 x 4096 focal plane array covering 4 square arc-min.



Each camera channel includes a focusing Offner relay, filter wheel, and retractable tunable filter.



Near-infrared camera module with solid model beams.

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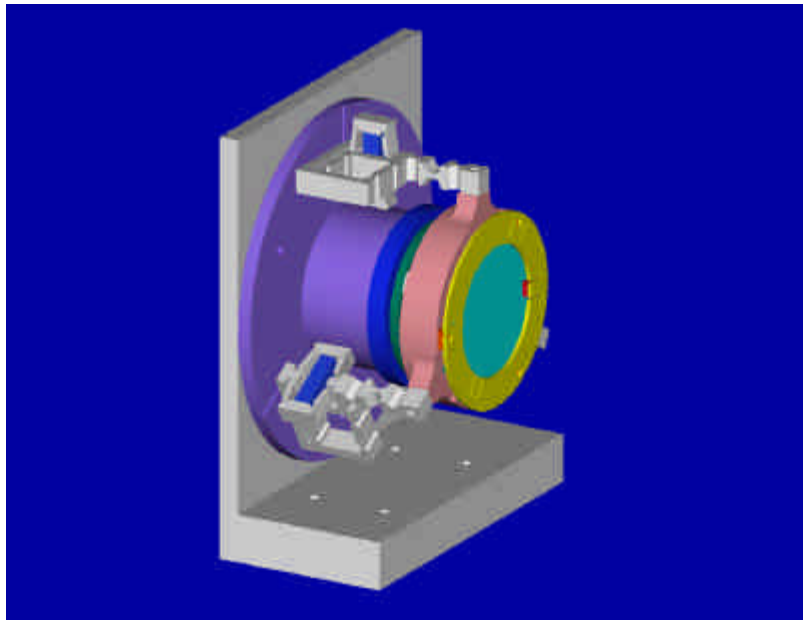
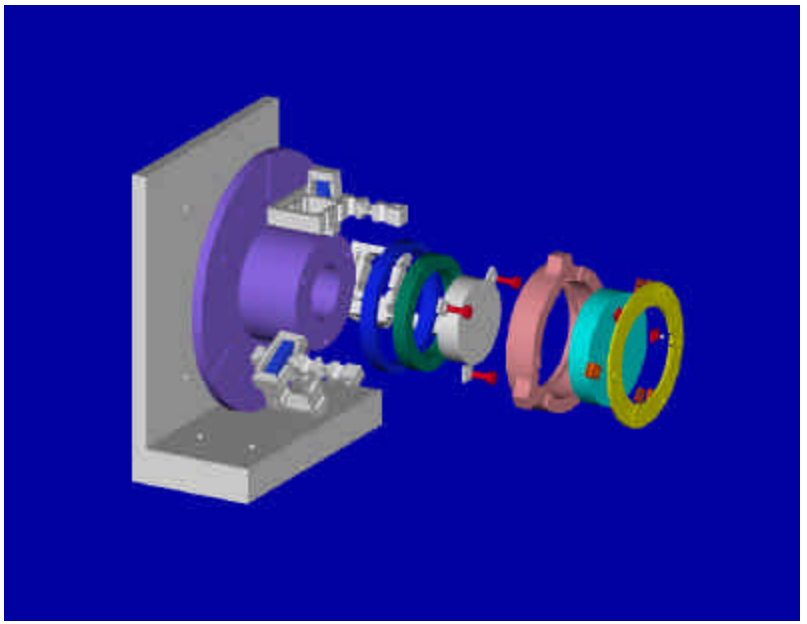
Demonstrator Unit for Low Order Cryogenic Etalon (DULCE)

- Prototype tunable filter for NGST wide field imagery at 50 < R < 200
- Under development by GSFC and Northrop Grumman Corp





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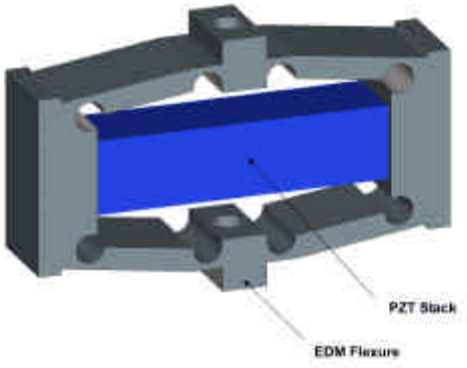
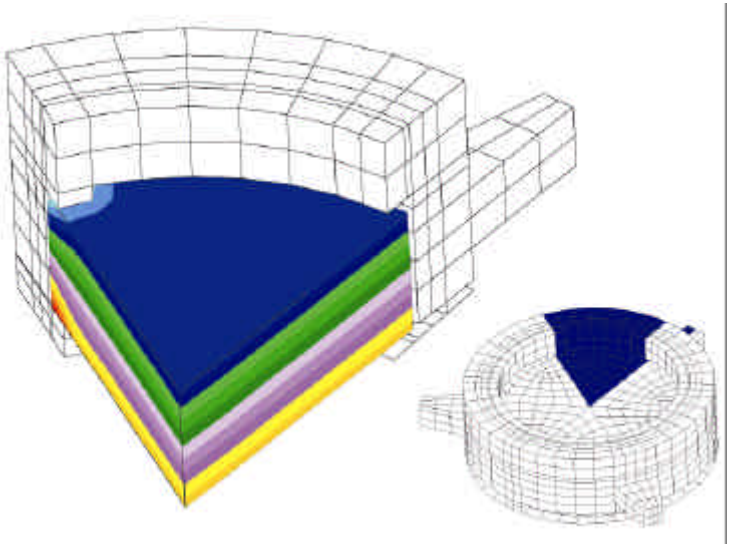
DULCE Technology Challenge Areas

- Low phase dispersion, low absorption dielectric mirror coatings for 1-5 microns
- Long stroke nm precision actuators for 30K operation
- Sub-micron gap etalon assembly for 30K operation
- High precision position servo control





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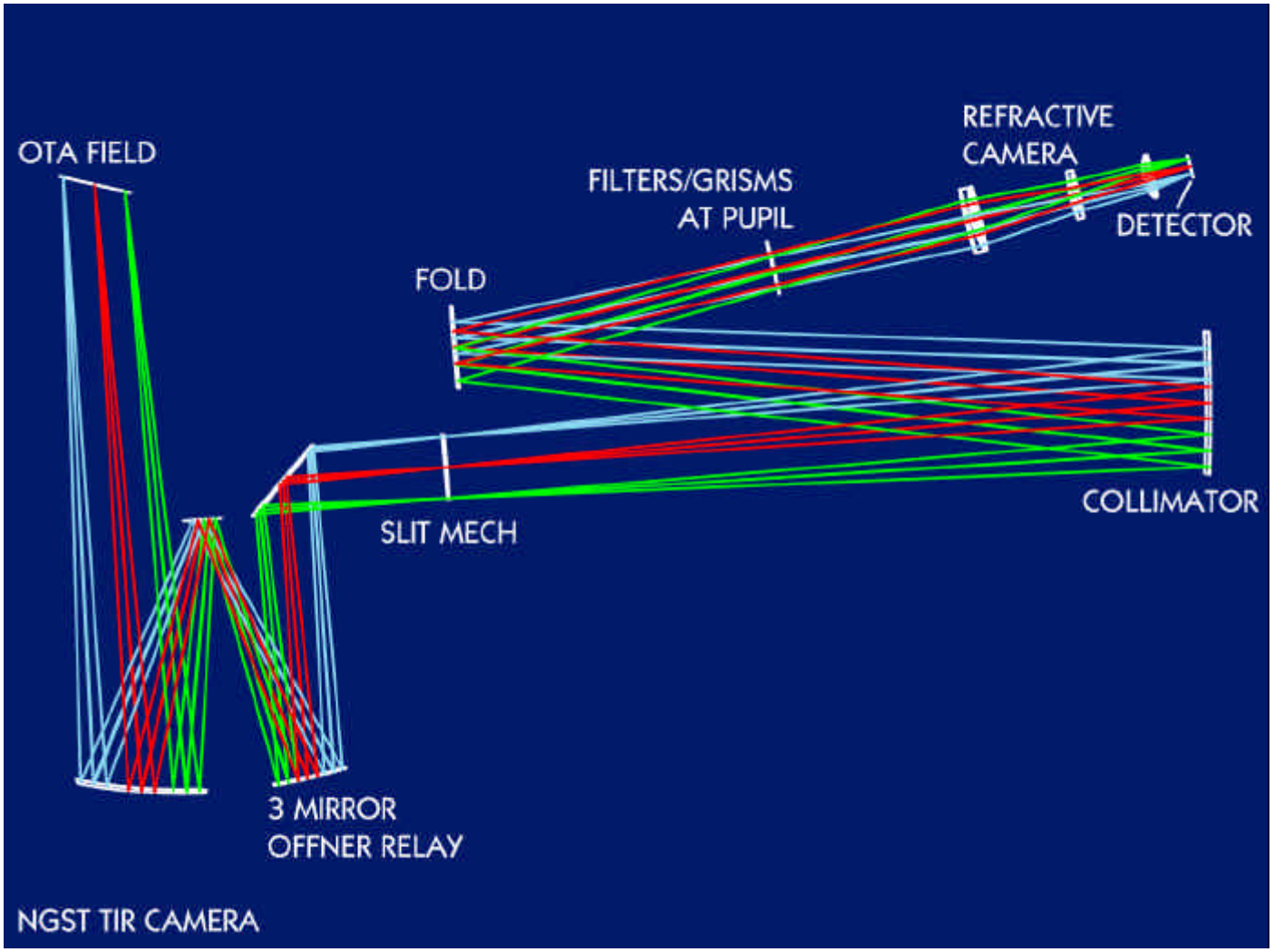
Mid-IR Camera/Spectrometer Optical Schematic



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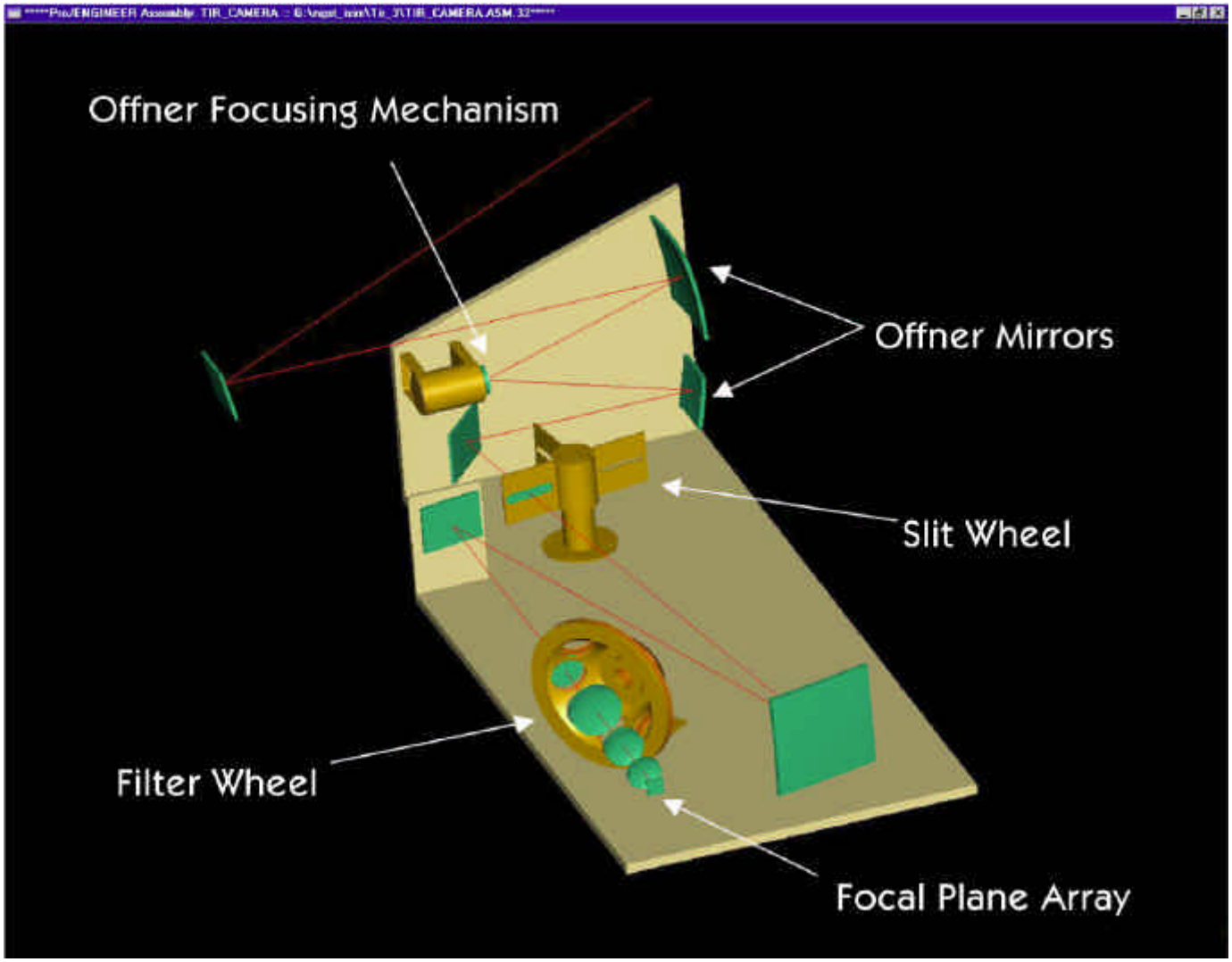
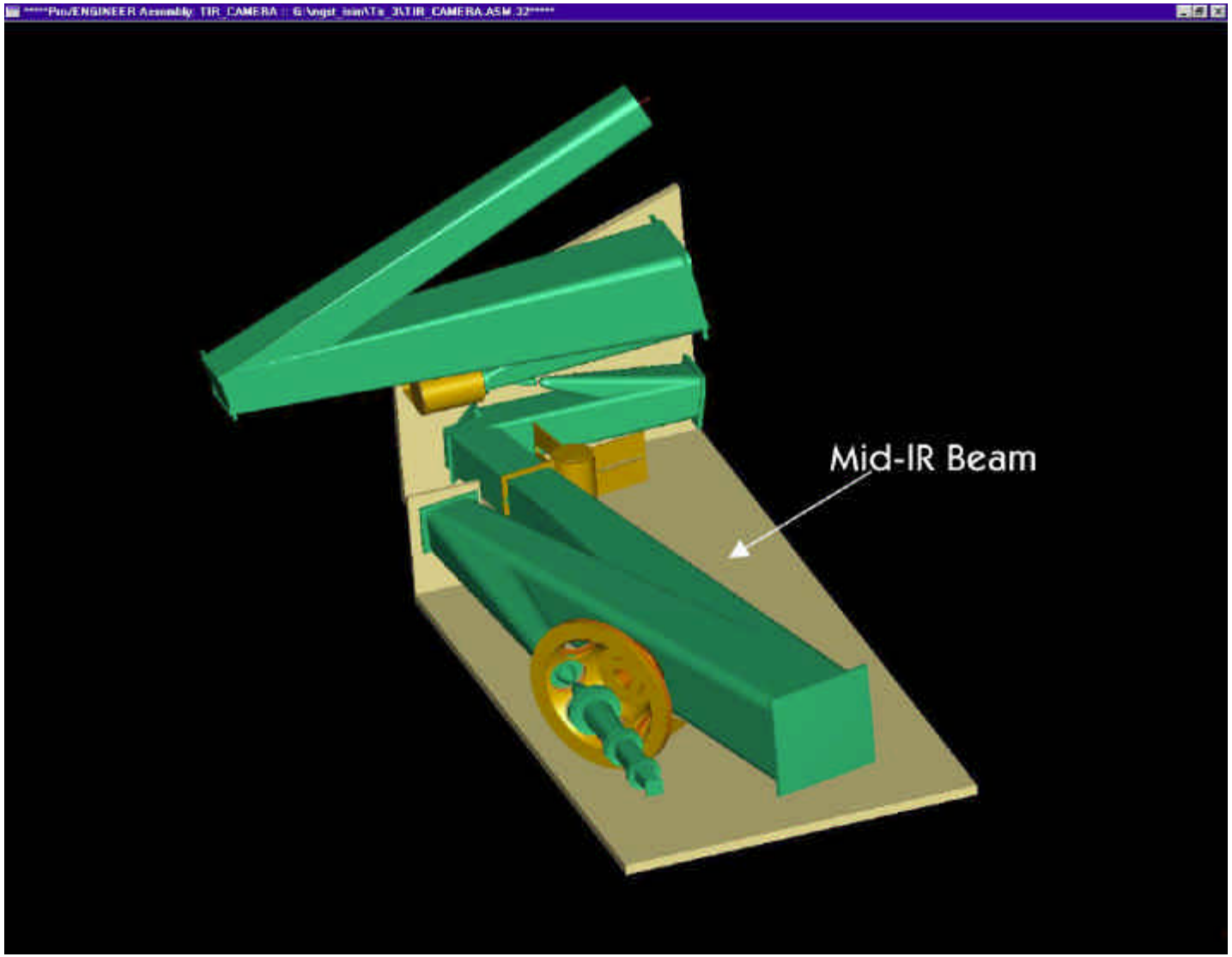
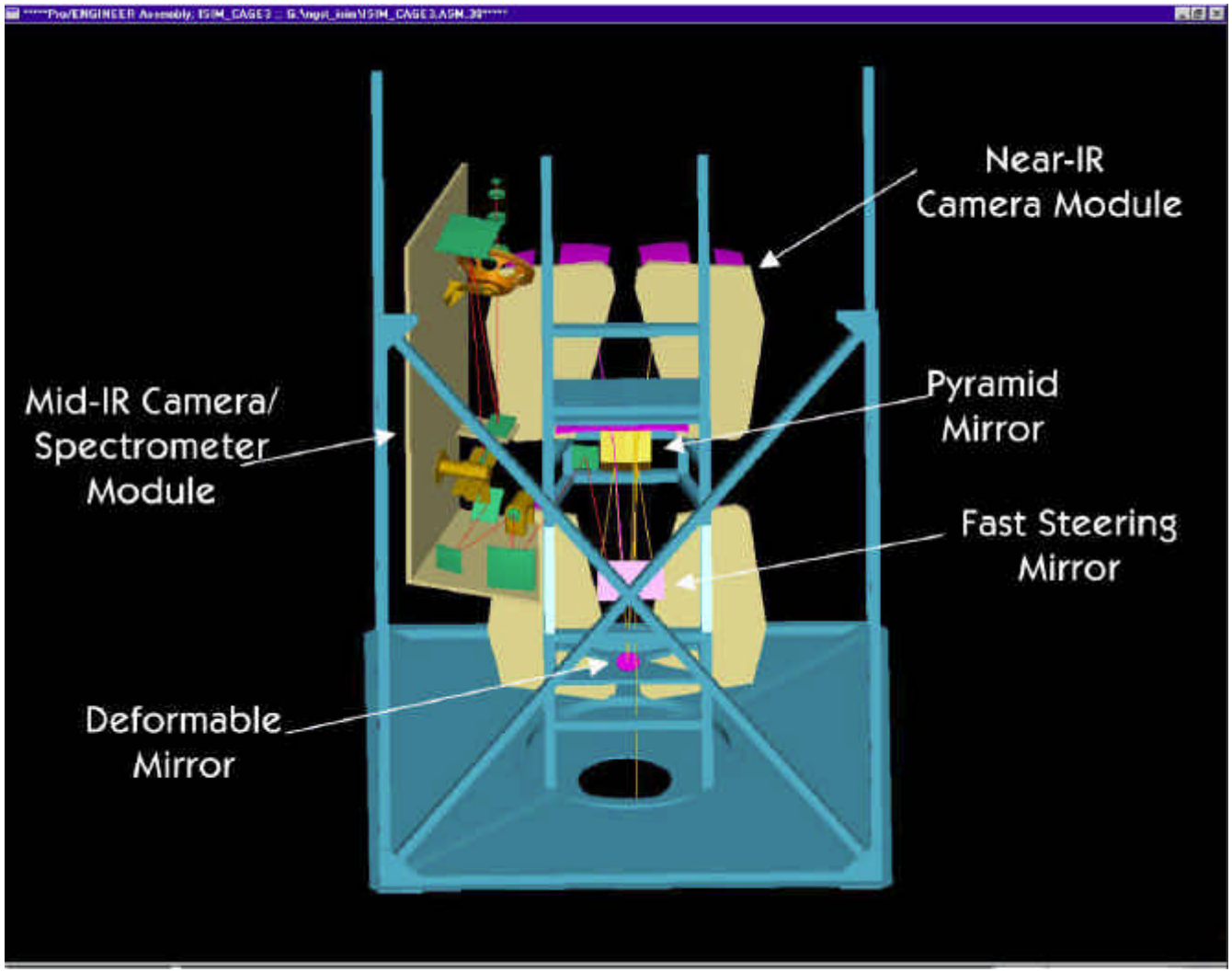


The mid-infrared camera/spectrometer module utilizes a 1024 x 1024 focal plane array and contains selectable slits, filters, and cross-dispersed grisms.



Mid-infrared camera/spectrometer module with solid model beams.



The near-ir camera and mid-ir camera modules integrate into the ISIM in a modular fashion. Near-ir spectrometer not shown.

Near-IR Micro-Mirror Array Spectrometer Optical Schematic

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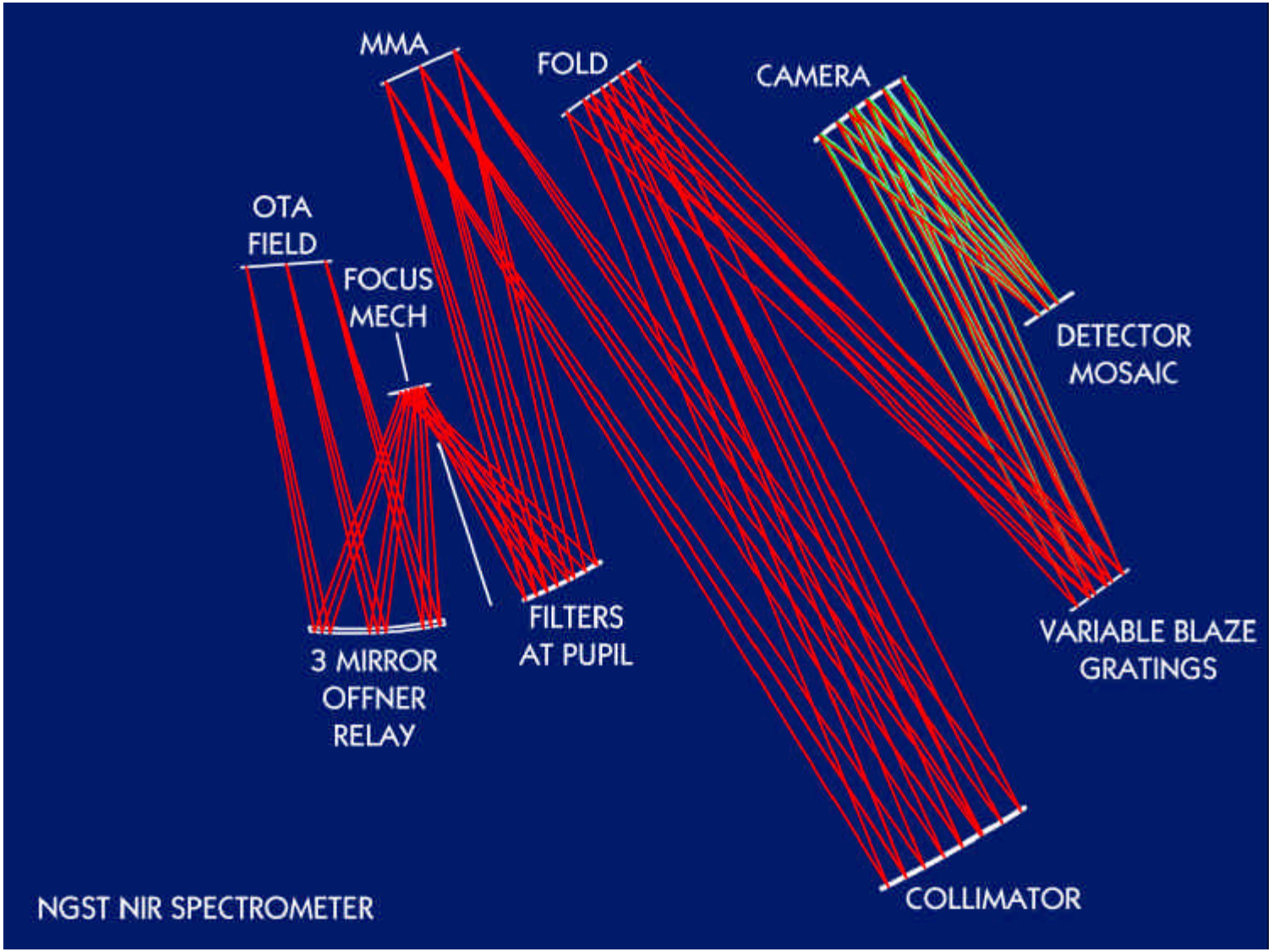

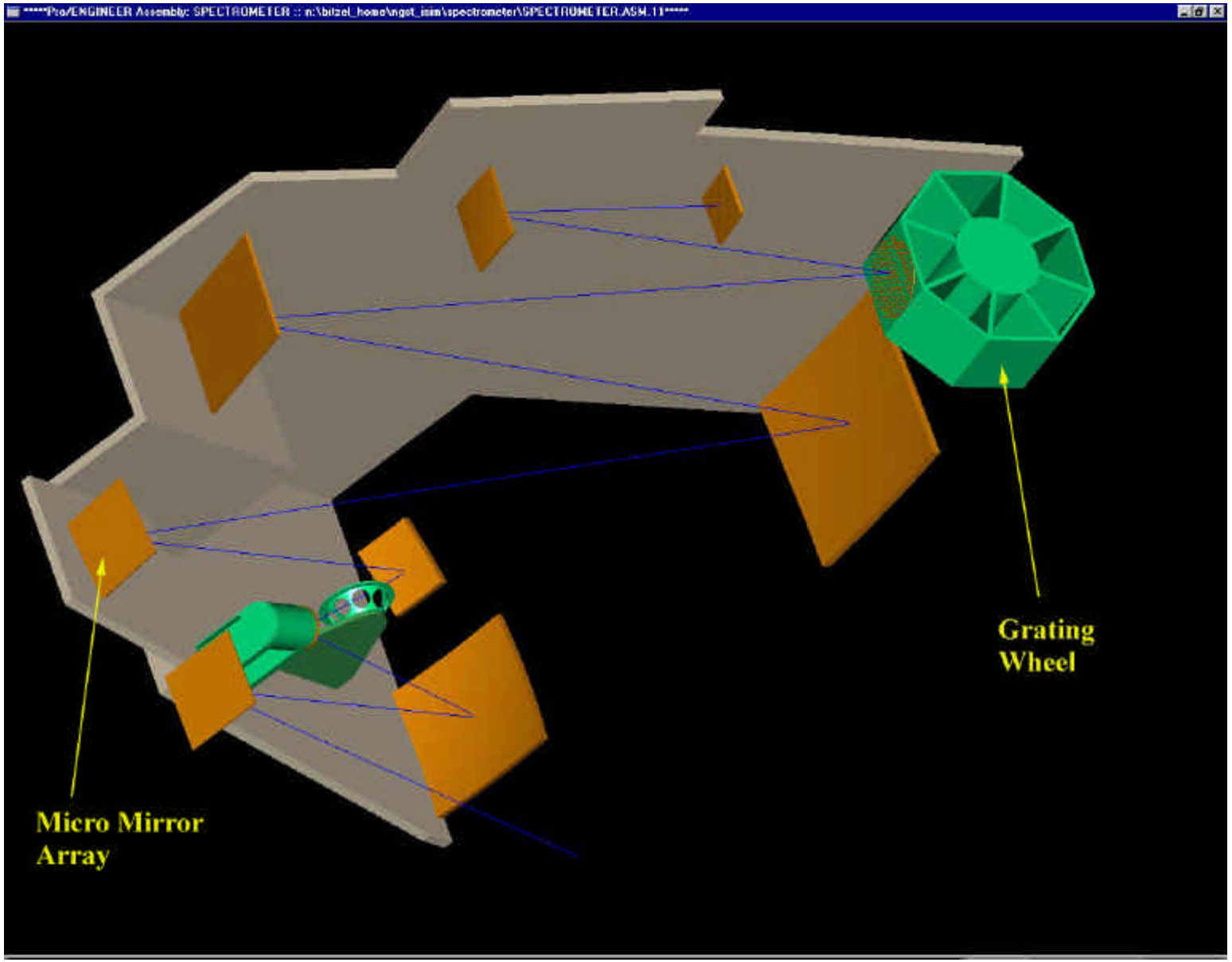
Grating
Wheel
Micro Mirror
Array

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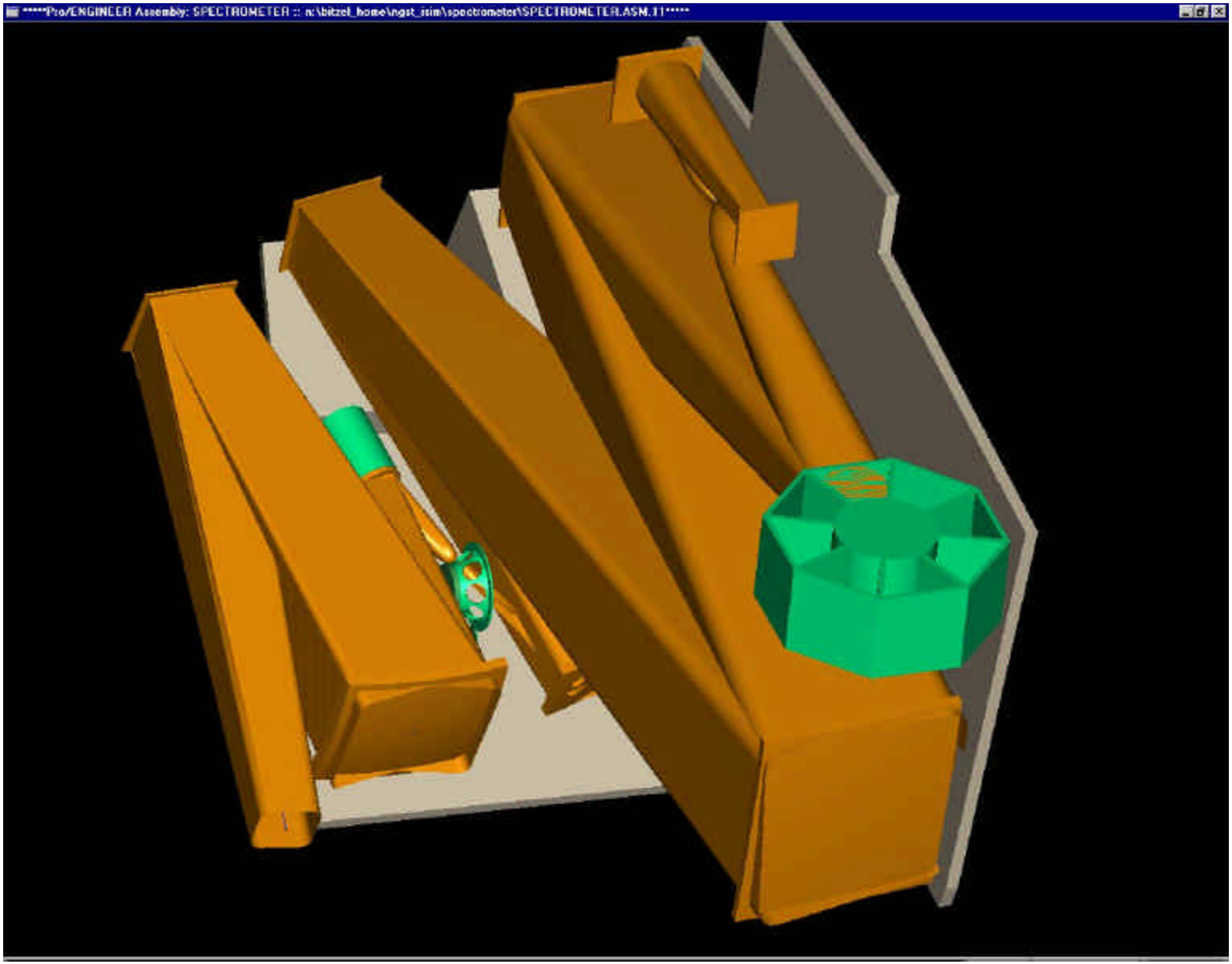

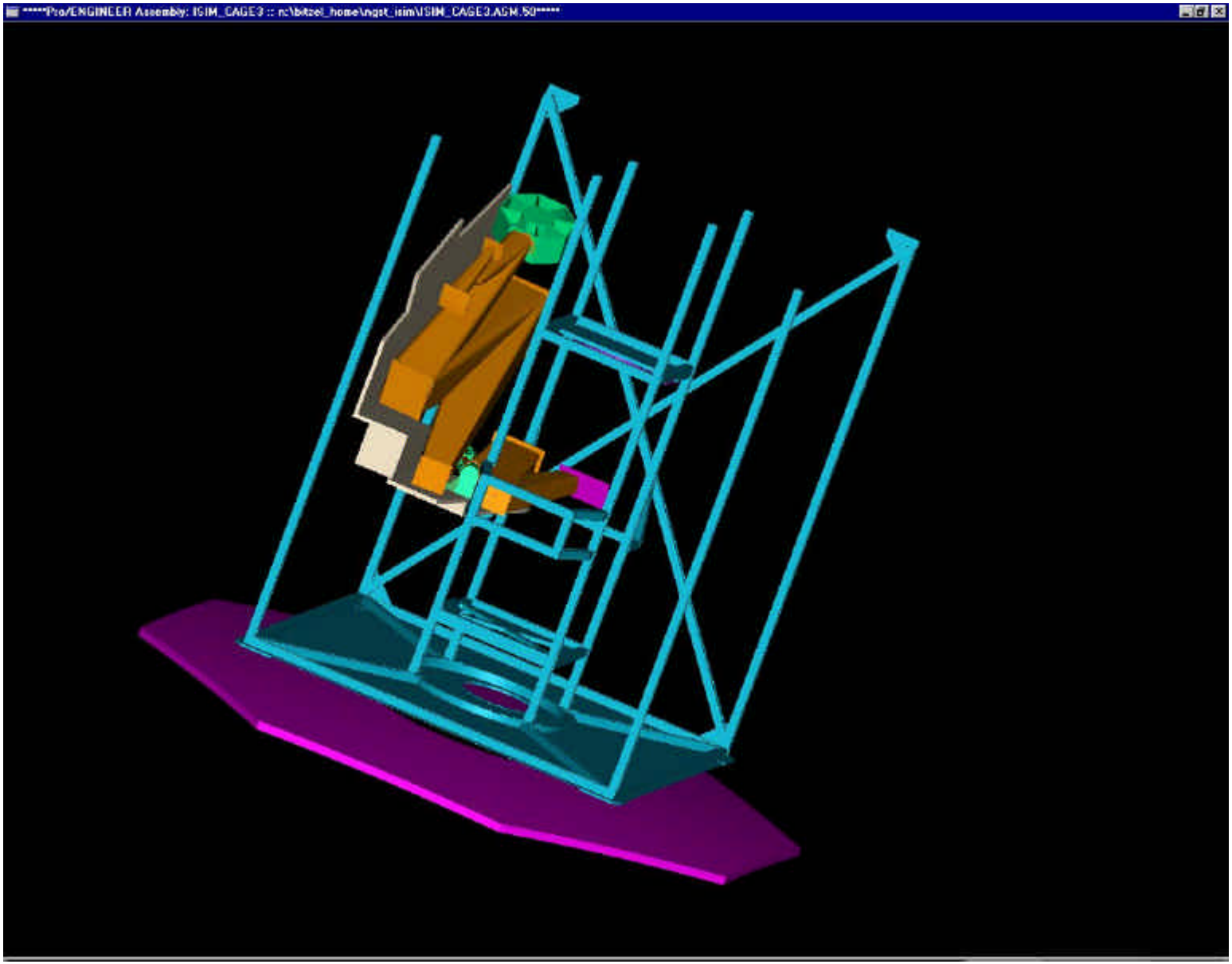
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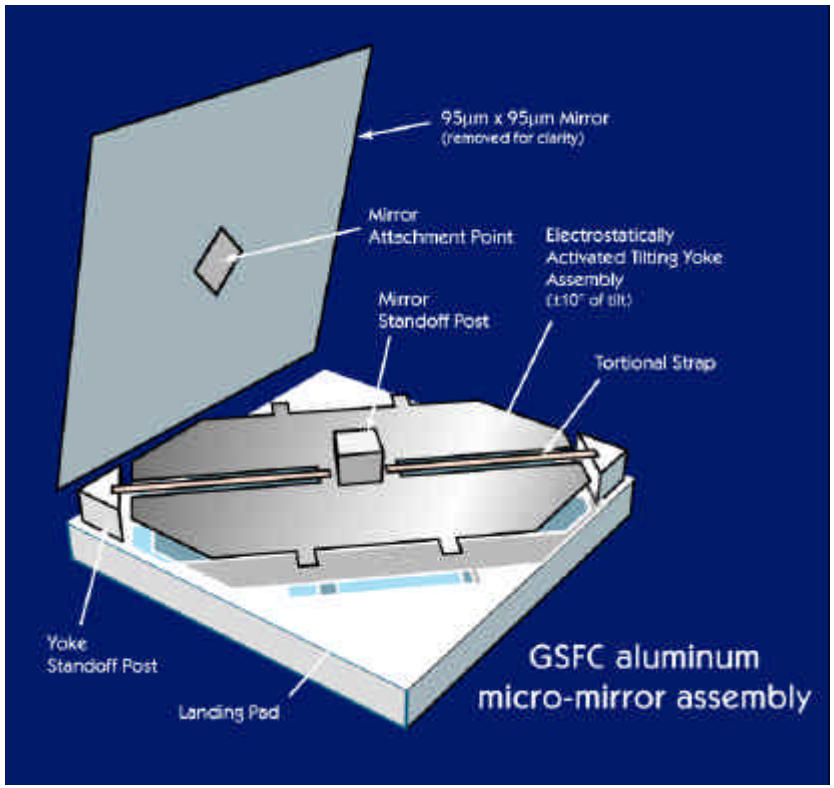
MEMS Sensor Optics

Cryogenic Micro-Mirror Arrays for Multi-Object Spectroscopy

- GSFC all aluminum design
  - prototype development started Jan 98
- Sandia National Labs all silicon design
  - prototype development started Nov 98
- 30 K operating temperature
- 100 micron pixel pitch
- surface micro-machining
- low voltage electrostatic actuation
- scalability goal: 2048 x 2048



STScI NGST-MOS Study

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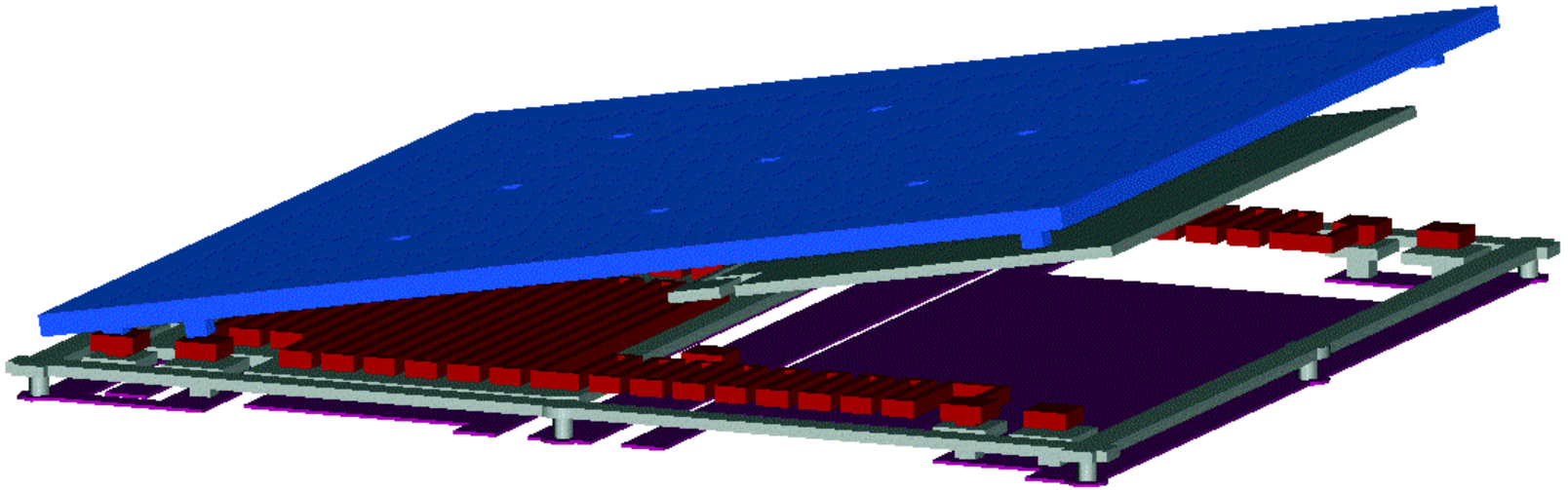
MEMS Sensor Optics

Cryogenic Micro-Mirror Arrays for Multi-Object Spectroscopy

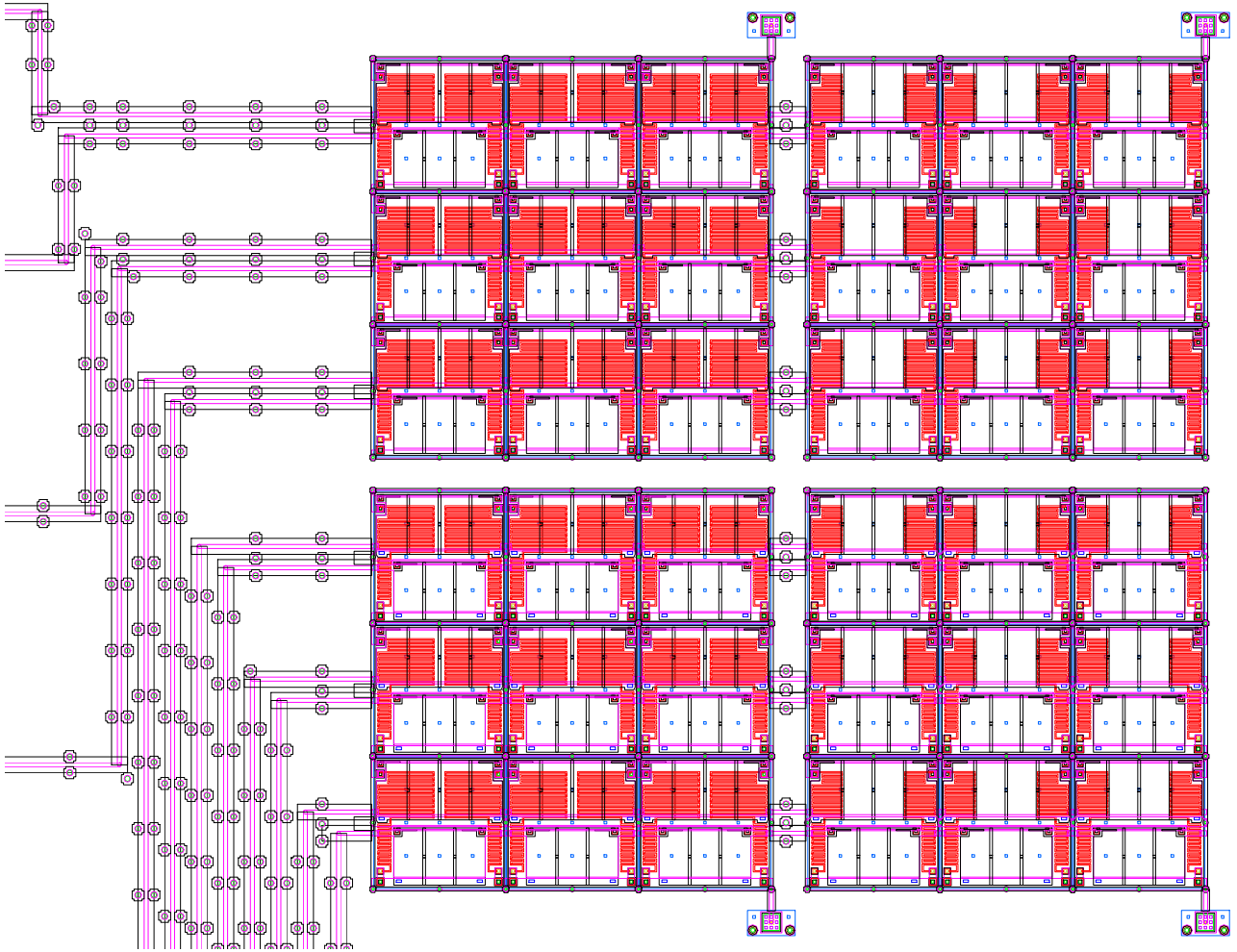
- Sandia National Laboratories
  - all silicon design
  - produced on existing commercial fab line



MEMS Sensor Optics

Sandia micro-mirror NGST prototype in fabrication

- first devices delivered June 99



Performance Exhibited By Current Detectors Is Near NGST Goals

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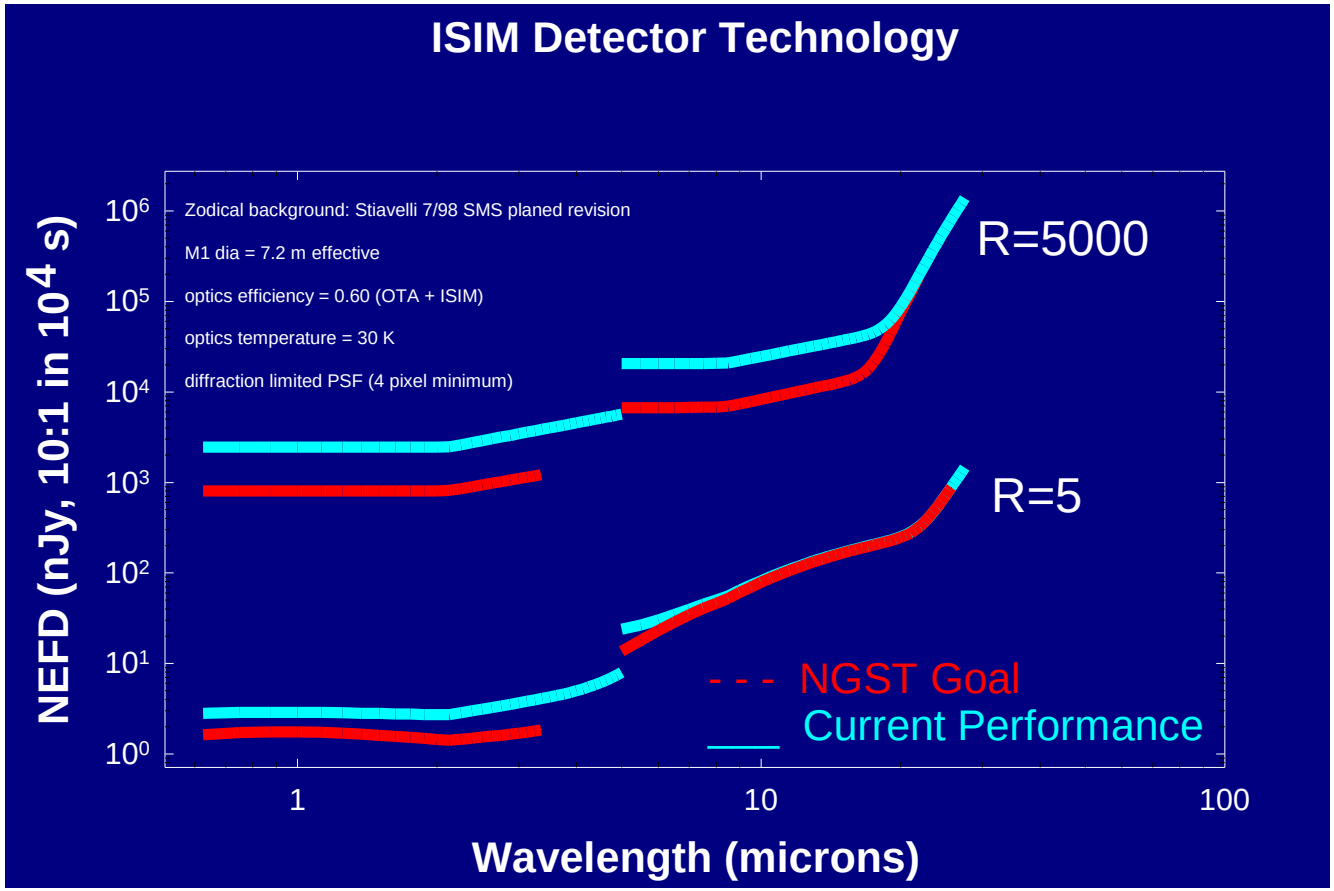

	QE	Read Noise (e) multiple read	Dark Current (e/s)
Alladin InSb	0.8	15	0.1
Near-IR goal	0.8	3	0.02
Current Si:As	0.5	8	10
Mid-IR goal	0.5	3	1

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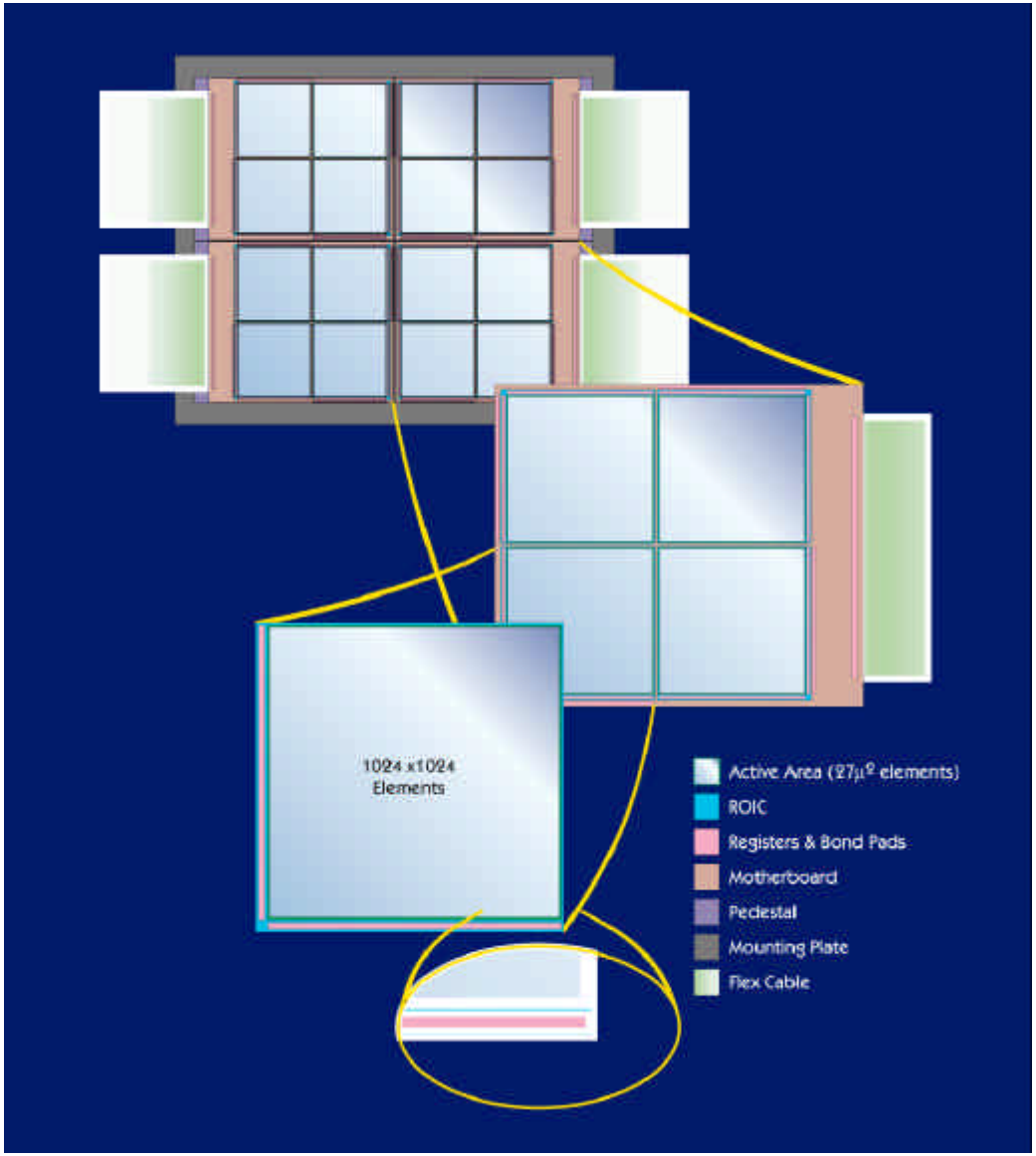
4096 x 4096 Near-IR FPA Assemblies



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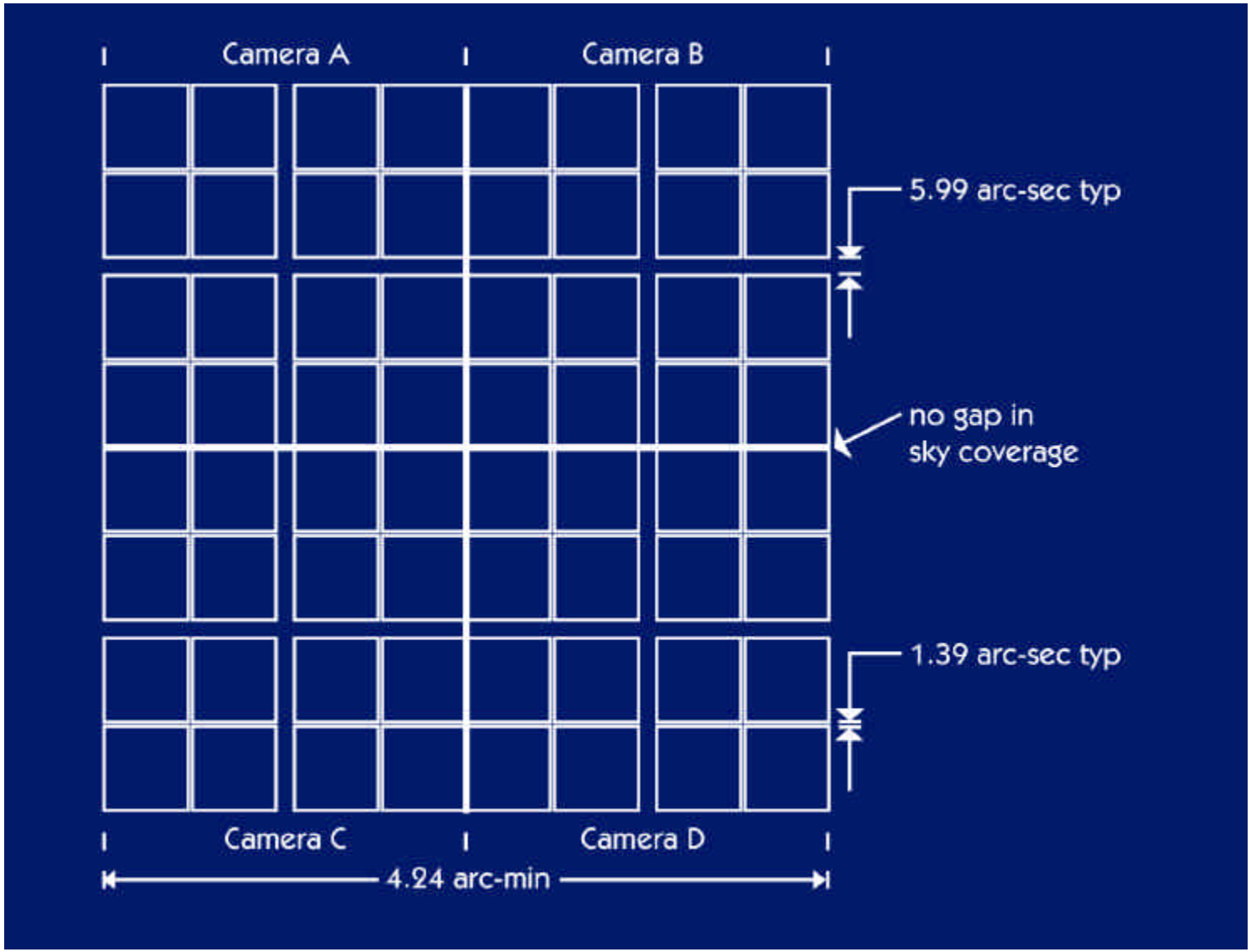
Near-IR Quad-Camera FOV



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Detector Technology Development

- Five technology development grants issued by NGST
- Near-ir 0.6 - 5 um
  - Raytheon IRCoE & University of Rochester
    - 1024 x 1024 InSb, buttable to 4k mosaic, 30K operation
  - Rockwell Science Center & University of Hawaii
    - 2048 x 2048 HgCdTe and Si p-i-n diodes, buttable to 4k mosaic, 30K operation
- Mid-ir
  - Raytheon IRCoE & NASA ARC & Cornell University
    - 512 x 512 Si:As, buttable to 1k mosaic, 6-8K operation, 5-28 um
  - Boeing Research & Technology Center
    - Si:Ga, 1k mosaic, 10-12K operation, 5-18 um
  - Rockwell Science Center & University of Rochester
    - HgCdTe, 25-30K operation, 5-10 um
- Funded by Ball Aerospace:
  - Raytheon IRCoE
    - 2048 x 2048 ROIC for InSb, low projected power dissipation

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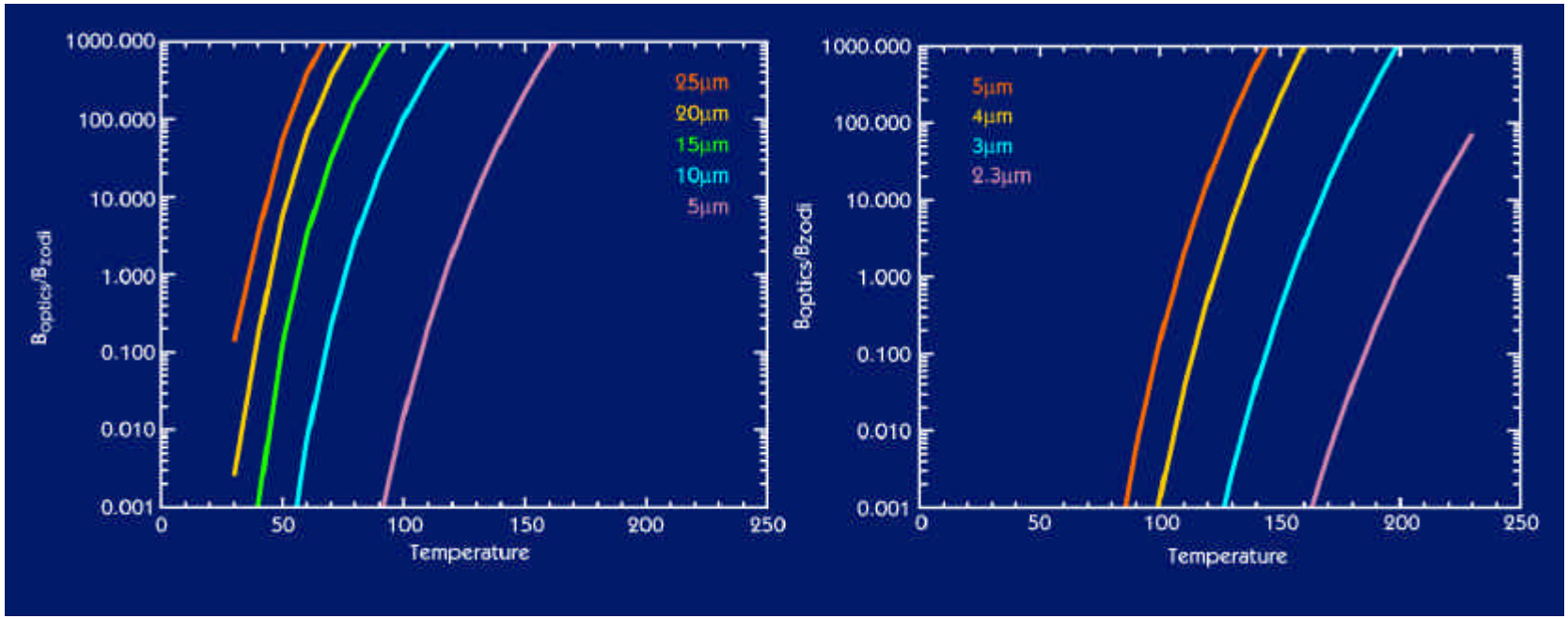
ISIM Cooling Requirements



ISIM optical bench temperature as a function of thermal background power relative to the Zodiacal light at various wavelengths.

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Thermal Radiator Configuration

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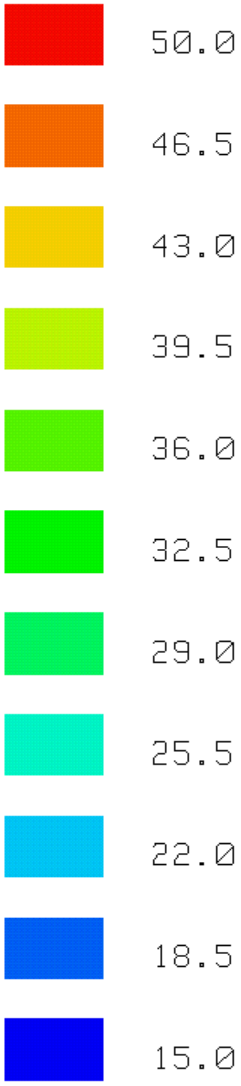
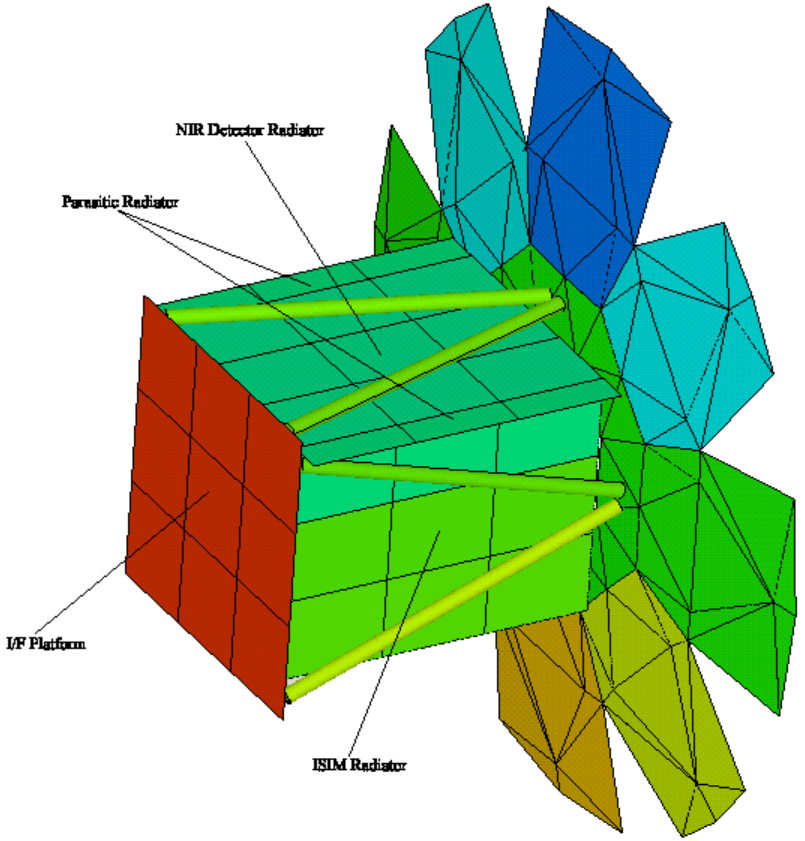
NGST





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NGST ISIM Top Level Heat Map

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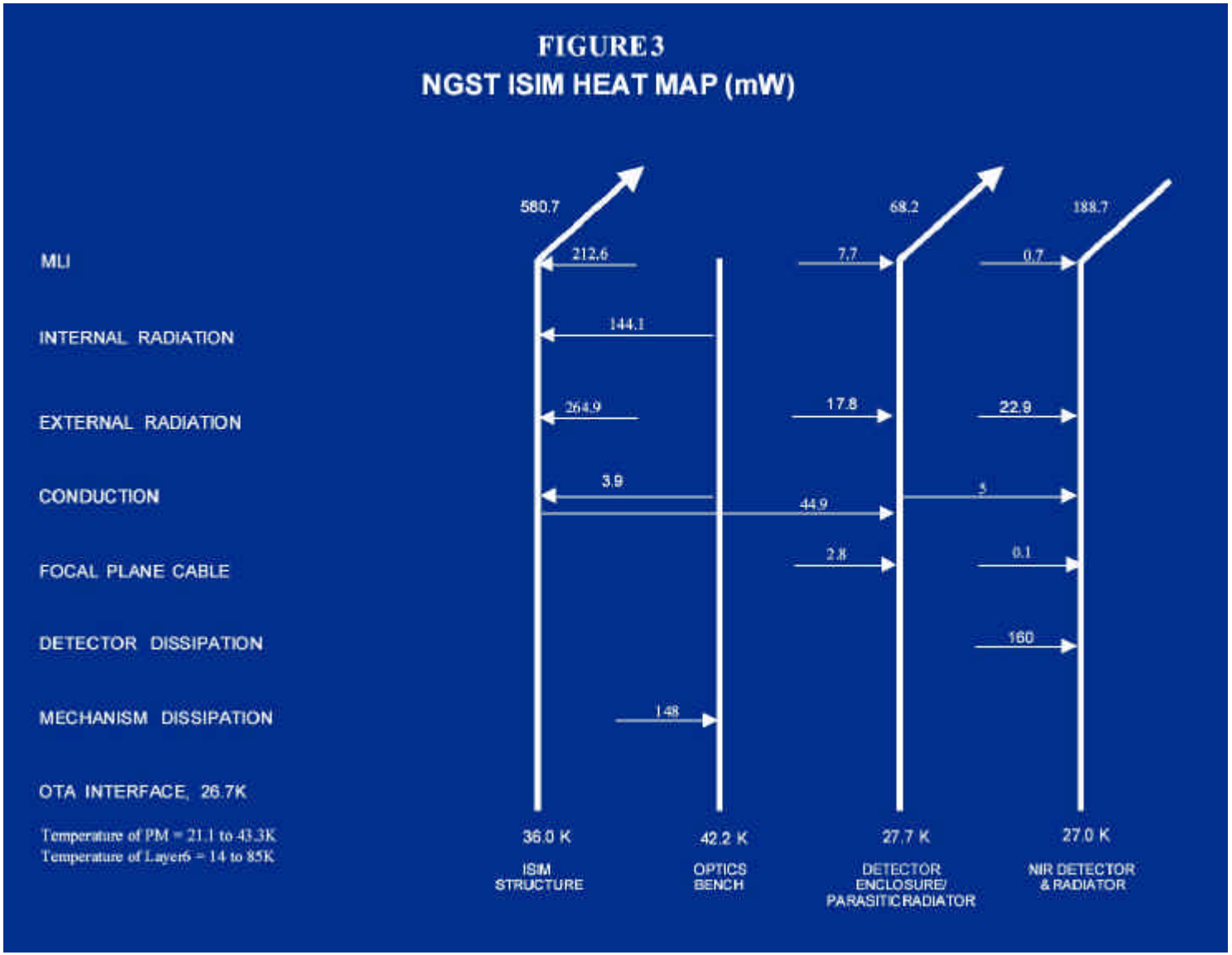

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ISIM Cooler Requirements

- Cooler required to enable any of the following design options:
  - warm (> 40 K) OTA
  - mid-infrared (> 5 micron) sensing with Si:As detectors
  - optical sensing with CCD detectors
- Exact requirements depend on options and involve two temperature regimes:
  - 0.6 watts of cooling at 25 K
  - 0.01 watts of cooling at 6 K
- Turbo-Brayton cooler technology developed by Creare Inc provide one of several solution paths

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Creare Miniature Turbo-Brayton Cooler

Key Features

- Vibration Free
- Robust gas bearings ensure long life
- Low mass, highly efficient, easy to integrate
- Ideal for use with radiatively cooled heat sink

Status

- 5 watt, 65 Kelvin engineering model has demonstrated long life
  - 70 K flight cooler produced for HST NICMOS
- 1 watt 35 K cooler demonstrated for the Air Force Research Lab

NGST Technology Development Goal

- 25K/ 6 K two stage demonstration cooler on life test by ~FY01

Funding

- Current development funded by NASA Cross Enterprise Technology
- Additional funding possible via NRA 2

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Grass Roots Cost Estimate

- Independent of previous estimates
- Detailed estimate using GSFC grass roots costing system
  - Formulation and Implementation Phase (A,B,C,D,)

- Basis of Estimate
  - ISIM designed, constructed, qualified by GSFC and delivered to Prime Contractor as GFE
    - realistic mix of CS and contract labor assumed
  - SI modules designed, constructed, qualified by external SI teams and delivered to GSFC for integration into ISIM
    - average aerospace contractor rate assumed
      - derived from current Ball, TRW, and LM contracts
    - both engineering and science labor force included

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Grass Roots Cost Estimate

WBS Number	Element	A	B	C/D	Launch	Total RY$K	Total FY96$K
1.0	Management	585	1,306	2,743	740	5,374	4503
2.0	Science	889	3,164	11,936	3,962	19,952	15,775
3.0	Systems	571	1,774	3,406	467	6,219	5,138
4.0	SR&QA	302	942	2,202	597	4,043	3,408
5.0	Structure	420	4,737	26,905	764	32,827	26,184
6.0	Optics	0	9,467	27,161	789	37,417	30,061
7.0	Electronics	380	3,333	24,540	718	28,970	23,716
8.0	Operations	0	0	0	0	-	-
9.0	Thermal	297	1,361	2,567	561	4,786	3,911
10.0	Software	267	1,021	10,797	1,195	13,280	11,103
11.0	Detectors	266	18,916	23,095	72	42,349	34,918
12.0	Cryo-cooler	15	305	9,735	968	11,023	8,572
Total in Real Year $ (K)		3,992	46,326	145,088	10,833	206,239	

Module	A	B	C/D	Launch	Total RY$K	Total FY96$K
ISIM Integrator	1,468	8,739	60,608	5,588	76,402	62,436
NIRCAM	1,064	19,287	39,014	1,751	61,117	49,635
NIRSPEC	720	8,835	22,659	1,836	34,050	27,323
MIRCAM	740	9,466	22,884	1,658	34,749	27,896
Total in Real Year $ (K)	3,992	46,327	145,166	10,833	206,318	

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FY98 accomplishments

- modular opto-mechanical layout solution
- accurate thermal model
- realistic design layout
  - technical budget assessment: volume, mass, power
  - grass roots cost estimate
  - ISIM requirements on OTA and SSM
- provide engineering context for NRA, ESA, and CSA studies

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Pre-Phase A FY99 goals

- development schedule
  - for ISIM
  - for FPAs and other technology development components
- structural analysis
  - concept validation
  - material trade
- confirm ISIM volume requirement
  - thermal mechanical layout
- limiting factors on maximum detector complement
  - thermal
  - front end electronics
  - data system
- continue synergism with NRA, ESA, and Prime Contractor study teams

ISIM IPT During NGST Phase A

- During Pre-Phase A, GSFC performed a detailed engineering study of an ISIM for the Yardstick observatory architecture.
  - http://www701.gsfc.nasa.gov/isim/isim.htm
- During Phase A, the ISIM IPT will evolve this design in two directions to integrate with two competing Prime Contractor NGST architectures.
  - GSFC will develop two proprietary designs
    - Implemented via single ISIM team with controlled lines of communication
  - IPT working relationships (GSFC, Primes, STScI, ESA, CSA) fully formed for:
    - smooth transition to Phase B
    - smart customer insight for mid-Phase B down select